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MILAN ARMY AMMUNITION PLANT O-LINE PONDS AREA FEASIBILITY STUDY

Focused Feasibility Study For Operable Unit One Groundwater Alternatives

FINAL DOCUMENT

June 1992

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FOCUSED FEASIBILITY STUDY FOR OPERABLE UNIT ONE - GROUNDWATER ALTERNATIVES
FOR -- TASK ORDER NO. 2
MILAN ARMY AMMUNITION PLANT
FEASIBILITY STUDY

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JUNE 1992

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13. ABSTRACT (*Maximum 200 words*)

A Feasibility Study is being conducted for the O-Line Ponds area at the Milan Army Ammunition Plant, TN. The purpose of the study is to identify remedial technologies which have the potential to treat, contain, or dispose of contaminated media and to develop remedial alternatives which will mitigate the risks posed to human health and the environment by conditions at the site. Additional field sampling and analysis will be performed to address the data gaps identified by the Remedial Investigation concerning the contaminant migration mechanisms at the O-Line Ponds. This Focused Feasibility Study report addresses remediation of Operable Unit 1, groundwater in the vicinity of and downgradient from the O-Line Ponds area. The report summarizes conditions at the O-Line Ponds area based on the RI, introduces and screens general response actions, technology types, and process options appropriate for remediation of groundwater (OU1) based on site-specific conditions and the potential to satisfy remedial action objectives. Process options are screened and developed into eight alternatives. Each alternative is evaluated in detail using the nine criteria identified in the NCP (40 CFR 300.430 (e)). A comparison of remedial alternatives is then performed.

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1.0 INTRODUCTION

ICF Kaiser Engineers (ICF) has been contracted by the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) to perform a Feasibility Study (FS) for the O-Line Ponds area. This work is being performed under Contract No. DAAA15-91-D-0014, Task Order 2. The purpose of the FS is to develop and evaluate remedial options such that an appropriate remedy may be selected for the site.

The O-Line Ponds area of the Milan Army Ammunition Plant (MAAP) is a site which formerly contained ponds used to precipitate explosive compounds from the waste stream generated by the demilitarization facility. These eleven ponds had a total area of approximately 280,000 ft^2 and were used nearly continuously from 1942 to 1978. In 1978, facility personnel elected to stop using the ponds because of the downgradient groundwater contamination detected at that time. The ponds were closed in 1982 with a multi-media cap to eliminate hydraulic loading on the contaminated sediments. A regular program of groundwater monitoring has since been implemented.

The Remedial Investigation (RI) performed in 1989-1991 by USATHAMA confirmed that the O-Line Ponds area has been a source of groundwater contamination and that residual soil contamination in the area may have a continuing impact on groundwater quality. The level of human health risks which could result from this contamination was determined to be unacceptably high at the northern boundary of the facility. In addition, a baseline risk assessment of the groundwater associated with the O-Line Ponds has since been conducted using the most recently available and complete analysis of groundwater quality. This assessment clearly indicates that should the O-Line Ponds area be developed for residential use prior to remediation, the human health risks associated with ingestion of untreated groundwater from the ponds area are unacceptably high.

To simplify evaluation of treatment alternatives and expedite site remediation, the O-Line Ponds unit has been divided into two Operable Units (OU):

- OU1 consists of groundwater in the vicinity of and downgradient from the O-Line Ponds which has been contaminated as a result of past disposal practices; and

- OU2 consists of soil in the vicinity of the O-Line Ponds and surface water and sediment in the ditch that flows along the east and north sides of the ponds, which have become contaminated as a result of past disposal practices.

This Focused Feasibility Study (FFS) Report addresses remediation of OU1. The specific project tasks addressed in this report are the following:

- Remedial action objectives have been developed for the specific contaminants, affected media, and exposure pathways;

- Remedial technologies which, alone or in combination, can treat, contain, or dispose of contaminated media have been identified;

- The remedial technologies have been screened to eliminate those that are not technically implementable, either based on attainment of chemical-specific ARARs or the volume of media which must be treated;

- As required by CERCLA/SARA, the remedial technologies have been assembled into remedial alternatives which, to the maximum extent practicable, utilize permanent solutions and alternative technologies;

- A detailed analysis of the remedial alternatives using the nine evaluation criteria listed in the NCP has been performed;

- Based on the detailed analysis of alternatives, the remedial actions have been ranked in order of preference.

This FFS has been conducted in accordance with U.S. Environmental Protection Agency (EPA) guidance documents developed for activities performed under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), and as implemented by the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 40 CFR 300; the National Environmental Policy Act of 1969 (NEPA); and the President's Council on Environmental Quality (CEQ) regulations (40 CFR 1500-1508). In addition, the procedures used in this study are consistent with the Department of the Army's policy toward integrating the NEPA and CERCLA/SARA processes.

1.1 ORGANIZATION OF REPORT

This report is divided into eight sections as follows:

Section 1.0 - Introduction
The purpose of the Focused Feasibility Study and organization of the report are presented.

Section 2.0 - Site Background
The site background and the results of the Remedial Investigation (RI) are presented. The discussion focuses on the results pertaining to the O-Line Ponds area.

Section 3.0 - Development of Remedial Action Objectives
Remedial action objectives are identified for the contaminated groundwater emanating from the O-Line Ponds area. These remedial action objectives consist of concentrations of groundwater constituents that meet health-based ARARs and to-be-considered guidance such as toxicity information and cancer slope factors.

Section 4.0 - Identification and Screening of Remedial Technologies
General response actions applicable to the site are identified. These general response actions are broken down into technologies and process options, which are then screened based on implementability, effectiveness and order-of-magnitude cost.

Section 5.0 - Development of Remedial Alternatives for Groundwater
Remedial alternatives for groundwater are developed by combining the remedial technologies that remain after screening. Vendor information was used to identify necessary pre- and post-treatment technologies.

Section 6.0 - Detailed Evaluation of Remedial Alternatives
Using the nine criteria identified in the NCP (40 CFR 300.430(e)), a detailed evaluation of remedial alternatives is performed.

Section 7.0 - Comparison of Remedial Alternatives
Based on the results of the detailed evaluation of remedial alternatives, a comparison of the alternatives is performed.

Section 8.0 - References

2.0 SITE BACKGROUND

The following section presents known information regarding MAAP and, specifically, the O-Line Ponds area. This includes information on the site history, physical setting of the area, and a summary of potential environmental problems identified at the site based on previous investigations, the RI, and the baseline risk assessment.

2.1 PHYSICAL SETTING

2.1.1 Location

MAAP currently covers 22,436 acres, and is situated in both Gibson and Carroll Counties (Figure 2-1.) The City of Milan lies 5 miles west of MAAP and has a population of 8,100; Humboldt lies 17 miles southwest with a population of 10,200; Trenton lies 18 miles northwest with a population of 4,600; and Jackson lies 28 miles south with a population of 50,000. The site is located approximately 60 miles east of the Mississippi River.

MAAP is serviced by two rail lines, two bus lines, several major truck lines, three US highways, and four state highways. Interstate 40 passes within 18 miles to the south of the plant.

2.1.2 Climatology

The MAAP area is characterized by a temperate and continental climate. Rainfall averages about 50 inches per year, with an average minimum of 2.9 inches in October and an average maximum of 6.0 inches in January. There is no dry season. Snowfall can be highly variable from year to year. The average annual evaporation is approximately 40 inches, and relative humidity averages 60-70%. The monthly mean temperature ranges from 40°F in winter to 80°F in July. The average frost free season is 215 days per year. The average depth of frost is 3 inches, with an extreme depth of 10 inches. Prevailing winds are from the south at an average velocity of 6-10 mph.

2.1.3 Site Physiography and Topography

MAAP is in the Gulf Coastal Plain Physiographic Province. Figure 2-2 is a relief map depicting the relationship of stratigraphic units to physiographic regions in Tennessee. MAAP lies within the coastal plain province of the Mississippi Embayment, west of the Western Valley of the Tennessee River and east of the Mississippi River Valley. The topography of the site and surrounding area is gently rolling to flat. It slopes regionally westward and contains numerous small streams, creeks, and drainage ditches. The elevation of the plant varies from a high of approximately 590 feet above mean sea level (ft-msl) on the south side to a low of approximately 320 ft-msl on the north boundary of the plant.

2.1.4 Surface Soil Types

The surface soils at MAAP consist chiefly of a reddish-brown to yellow mottled silty clay that grades into a clay unit with depth. The soil types include the Memphis, Loring, Henry, Falaya, and Waverly soil associations. Based on topography, the Memphis and Loring series occur on higher elevations and are well-drained soils. The Henry soil series is somewhat poorly drained and is usually associated with flat terrain while the Falaya and Waverly occur in the low areas and are poorly drained.

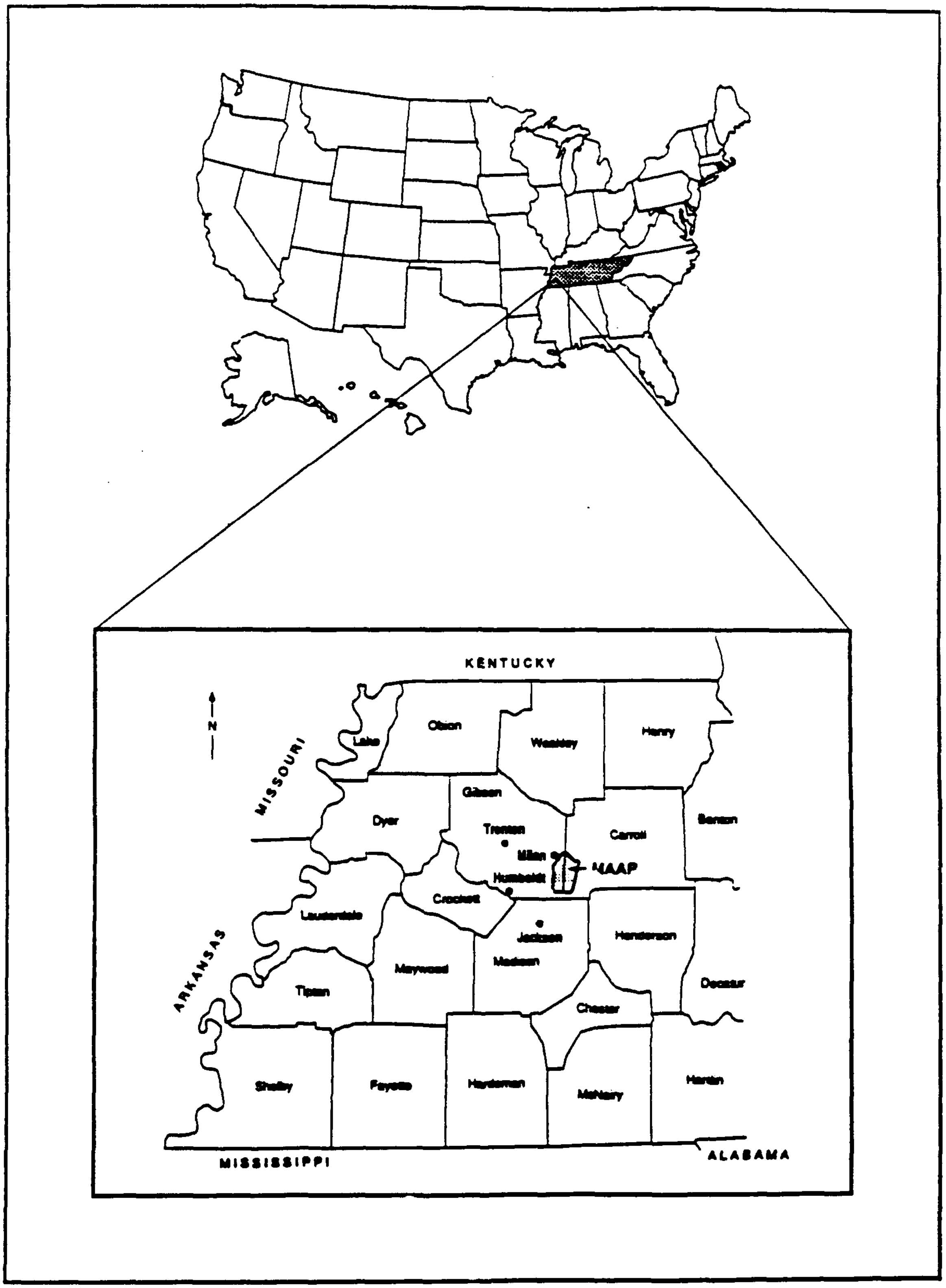
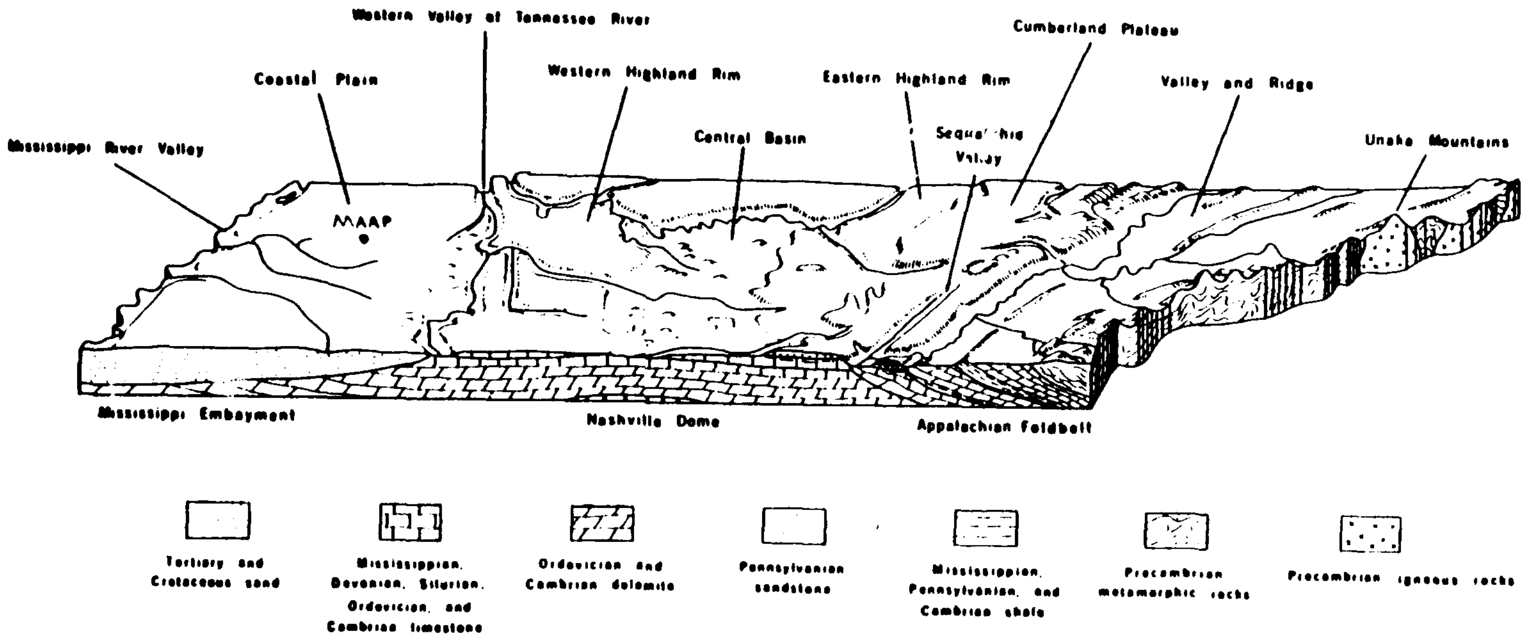


Figure 2-1
Location of MAAP in Western Tennessee



Source: Miller 1974

Figure 2-2
Relationship of Stratigraphic Units to Physiographic Regions in Tennessee

Drill logs from borings installed at the site indicate that the upper 12 to 15 feet of soil consists of reddish-brown to tan silty lean clay with some layers of sandy and fat clay. Below these depths, sands with varying amounts of silts and clays have been encountered. Occasional gravel, up to 3/8 inch in diameter, have been encountered during boring operations. A more sandy alluvium of lesser thickness (5-10 feet) was observed in several areas across the site. Natural and artificial drainage systems have incised into the alluvium in several locations.

2.1.5 Site Soil Profile and Geology

Western Tennessee (including MAAP) lies on the eastern flank of the Upper Mississippi River Embayment. Structurally, the embayment is a downwarped, downfaulted trough whose axis approximates the present course of the Mississippi River. Sediments ranging in age from Cretaceous to Recent have been deposited in this trough during its complicated history which included advances and regressions of the sea. These sediments consist of sand, gravel, lignite, clay, chalk, and limestone units that vary in thickness.

MAAP is situated on the Memphis Sand of the Claiborne Group of Tertiary age in the Gulf Coastal Plain of western Tennessee. Figures 2-3a and 2-3b show a roughly east-west geologic cross section developed from lithologic and geophysical logs of observation wells in Dyer County (Dy:H-7, Dy:H-41), Gibson County (Gb:M-6; Gb:G-5), and Carroll County (Cr:F-15), as described in Parks and Carmichael (1990). The altitude and thicknesses of stratigraphic units beneath Milan, Tennessee, are inferred from the data for observation wells in Gibson and Carroll Counties.

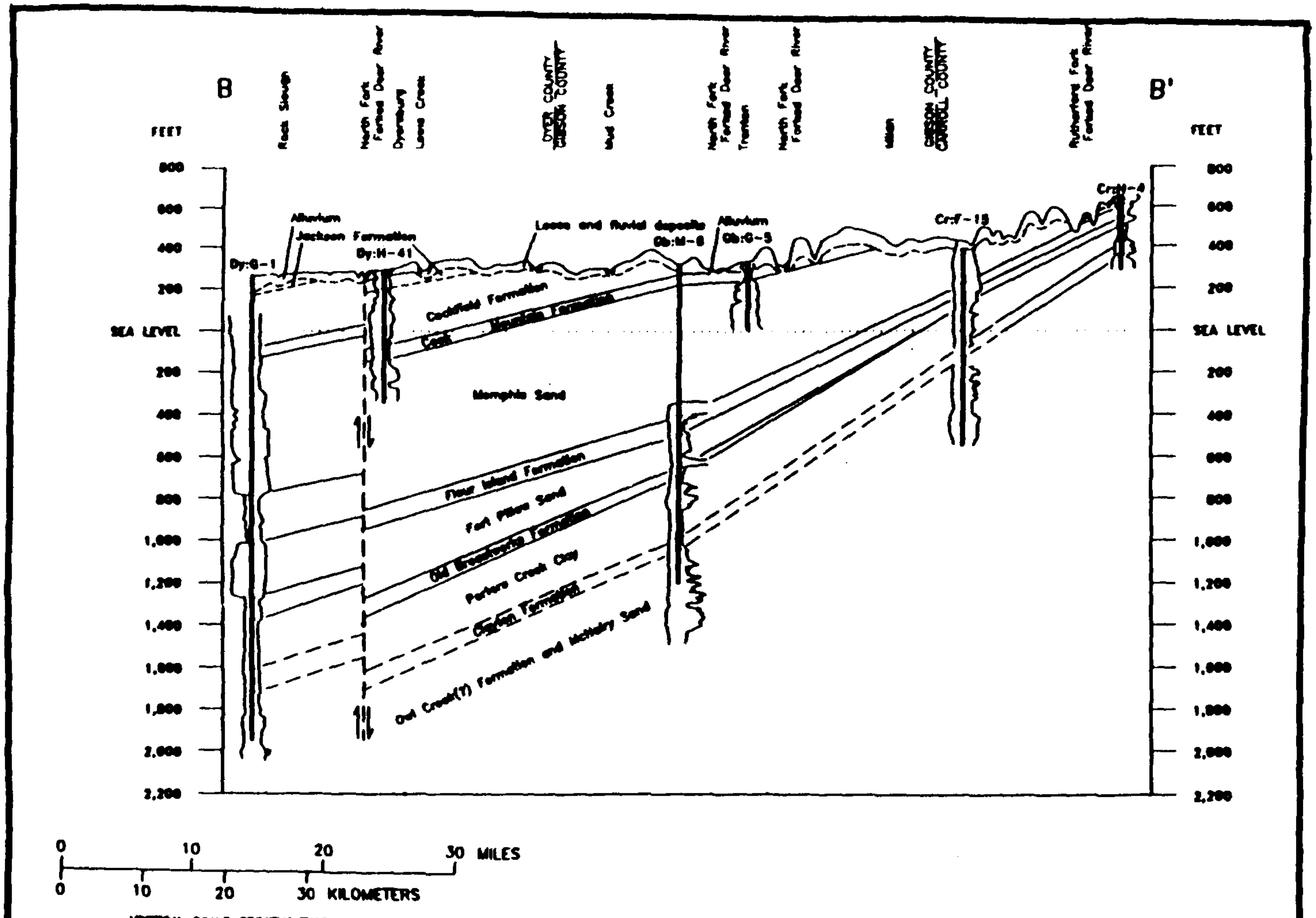
The Memphis Sand crops out in a broad belt across western Tennessee, but is covered in most places by fluvial deposits of Tertiary and Quaternary age and loess and alluvium of Quaternary age (Parks and Carmichael, 1990). The eastern boundary of the Memphis Sand was mapped by Parks and Russell (1975) as the contact between the Wilcox and Claiborne Formations. The Wilcox and Claiborne were mapped as formations because of the uncertainty of the equivalence of strata cropping out with the units that make up the Wilcox and Claiborne Groups in the subsurface, as subdivided by Moore and Brown (1969) (Parks and Carmichael, 1990). The western boundary of the outcrop belt is not well established because the contact between the Memphis Sand and the overlying Cook Mountain Formation is covered by fluvial deposits, loess or alluvium (Parks and Carmichael, 1990).

The Memphis Sand consists of a thick body of sand that includes subordinate lenses or beds of clay and silt at various horizons. It was observed during borehole drilling and sampling that the clay and silt lenses vary in thickness. Most of these lenses were 0.04 to 0.5 feet thick. The clay and silt locally are carbonaceous and lignitic; thin lenses of lignite also occur locally. Thick beds of clay and silt in the upper part of the Memphis Sand may, in some places, be confused with the overlying Cook Mountain Formation.

The sands in the Memphis Sand range from very fine- to very coarse-grained, but are commonly fine-to-medium and medium-to-coarse grained. The color of the sands varies, but is predominately white, brown, yellow or gray with minor occurrences of reddish-yellow to red sands occurring as thin bands within the white, yellow, brown and gray sand zones. The sand is thick-bedded, with grain sizes varying vertically as well as laterally. Thin layers of indurated rock fragments were encountered during drilling and are probably erosional lag deposits from an iron-cemented sandstone source.

The Memphis Sand unit ranges from 0 to 900 feet in thickness, and where the original thickness is preserved, it is about 400 to 900 feet thick (Parks and Carmichael, 1990). The formation is thinnest along the eastern limits of the outcrop belt in Hardeman, Madison, Carroll and Henry counties. In western Tennessee, the base of the Memphis Sand dips westward at rates of 20 to 50 feet per mile.

Figure 2-3a
E/W Geologic Cross-Section Through Dyer, Gibson, and Carroll Counties, Tennessee



Source: Parks and Carmichael 1990

Figure 2-3b
E/W Geologic Cross-Section Through Dyer, Gibson and Carroll Counties, Tennessee

The Flour Island Formation of the Wilcox Group is the lower confining unit for the Memphis Sand and consists predominantly of clay and silt (Parks and Carmichael, 1990). The thickness of this unit beneath the Milan area is estimated to be 50 feet based on the geologic cross section shown in Figure 2-3b. It is believed that this unit was encountered at a depth of 245 feet at a borehole on the northern facility border. Underlying the Wilcox Group is the Porters Creek Clay, which acts as a confining unit between the Fort Pillow Sand of the Wilcox Group and the McNairy Sand of Cretaceous age.

Approximately 10 to 20 feet of alluvium was encountered in each borehole. The alluvium consisted of a yellowish brown to strong brown, loamy, silty clay. The silty clay was loose to moderately stiff with low plasticity, and contained varying amounts of organic material. The alluvium is underlain by the sands, silts and clays characteristic of the Memphis Sand. Previous investigators at MAAP have speculated that the Porter Creek Clay is the lower confining unit for this aquifer. However, this clay unit was not encountered during drilling. A detailed review of the available information concerning the regional geology has shown that the thickness of the Memphis Sand is greater than previously thought, and this was confirmed by the results of the drilling.

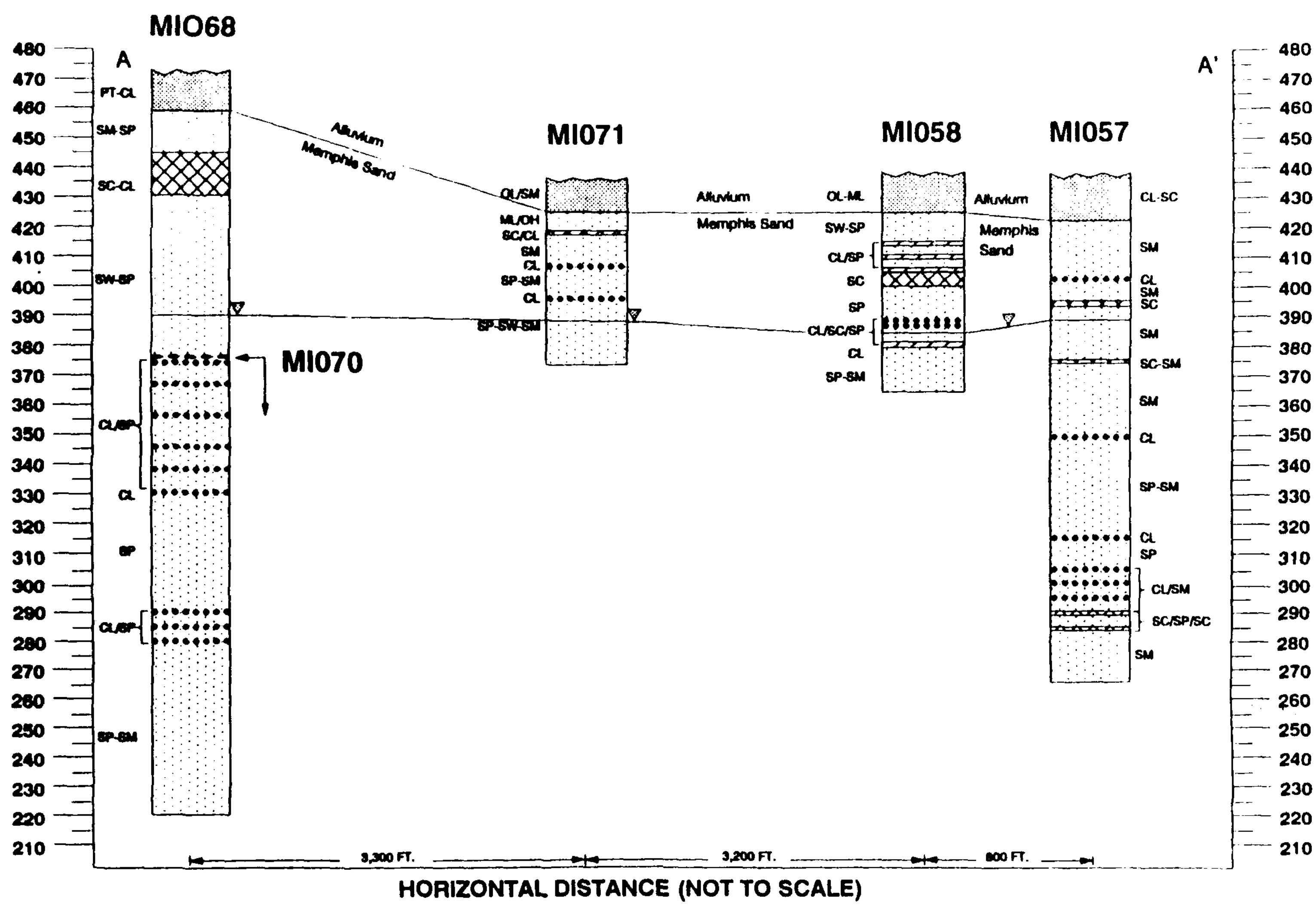
East-west and north-south soil profiles were developed from the soil boring logs of monitoring wells installed during the RI at MAAP (Figures 2-4 and 2-5). The locations of the monitoring wells used in developing these profiles are shown in Figure 2-6. These soil profiles indicate that the lithology varies both vertically and laterally over short distances. Wells MI057 and MI058 were 800 feet apart, and from the stratigraphic columns shown in Figure 2-4, it is evident that the occurrence and thickness of the clay zones changes considerably over short distances. Therefore, correlation of stratigraphic units has not been attempted because of the lateral variations in lithology and absence of laterally continuous and recognizable stratigraphic units.

The exact depth to rock under MAAP is not known. A test well drilled to 1,289 feet about 20 miles south-southwest of MAAP near Jackson, Tennessee, was stopped in a sandy clay marl. It was estimated that rock (possibly limestone) would be encountered between 500 to 800 feet below the drilled depth of the test well.

There are no mapped faults in the immediate area of MAAP (Tennessee Geologic Survey, 1978). However, the primary concern at the installation is its proximity to the New Madrid Seismic Zone, one arm of which extends almost to Dyersburg, Tennessee, 40 miles northeast of the plant (Stevens, 1989). The Tennessee Earthquake Center records an average of 150 earthquakes a year in this zone; consequently, Milan is in close proximity to major seismic activity (Algermissen and Hopper, 1984).

2.1.6 Site Surface Water Hydrology

Numerous perennial and ephemeral surface water features occur within the installation and flow to the north-northwest as depicted in Figure 2-7. Wolf Creek, the largest interior drainage body, originates at Pine Lake near the southeastern boundary (not depicted in Figure 2-7) and along with three tributaries (Dry Creek, East Fork of Wolf Creek, and West Fork of Wolf Creek) drains the southern and central portions of the installation. Wolf Creek exits along the northwest boundary and empties into the Rutherford Fork of the Obion River. The extreme southern portion of the installation drains south to the Middle Fork of the Forked Deer River (not depicted in Figure 2-7). The northeastern portion of the installation drains to Halls Branch, Johns Creek and then to the Rutherford Fork of the Obion River. The northern portions of MAAP contain several well-developed, ephemeral, natural drainage bodies (including Ditches 4, 5, B, and C shown in Figure 2-7) that join the Rutherford Fork along the northern boundary of the installation. The two parent streams, the Forked Deer River and Obion River, empty into the Mississippi River about 60 miles west of MAAP.



CL - Lean clay, sandy clay, silty clay, of low to medium plasticity
ML - Silt and very fine sand, silty or clayey fine sand or clayey silt with slight plasticity
OL - Organic silts and organic silty clays of low plasticity
PT - Peat or other highly organic soil
SC - Clayey sand, sand-clay mixtures
SM - Silty-sand, sand-silt mixtures
SP - Sand, poorly graded, gravelly sands
SW - Sand, well-graded, gravelly sands

Sandy/Silty/Clay/Loamy Soil
Sandy/Silty Clay
Clay
Sand
•••• Clay Layers 0.5-6 inches thick
Water Table

Figure 2-4
East/West Soil Profile at MAAP

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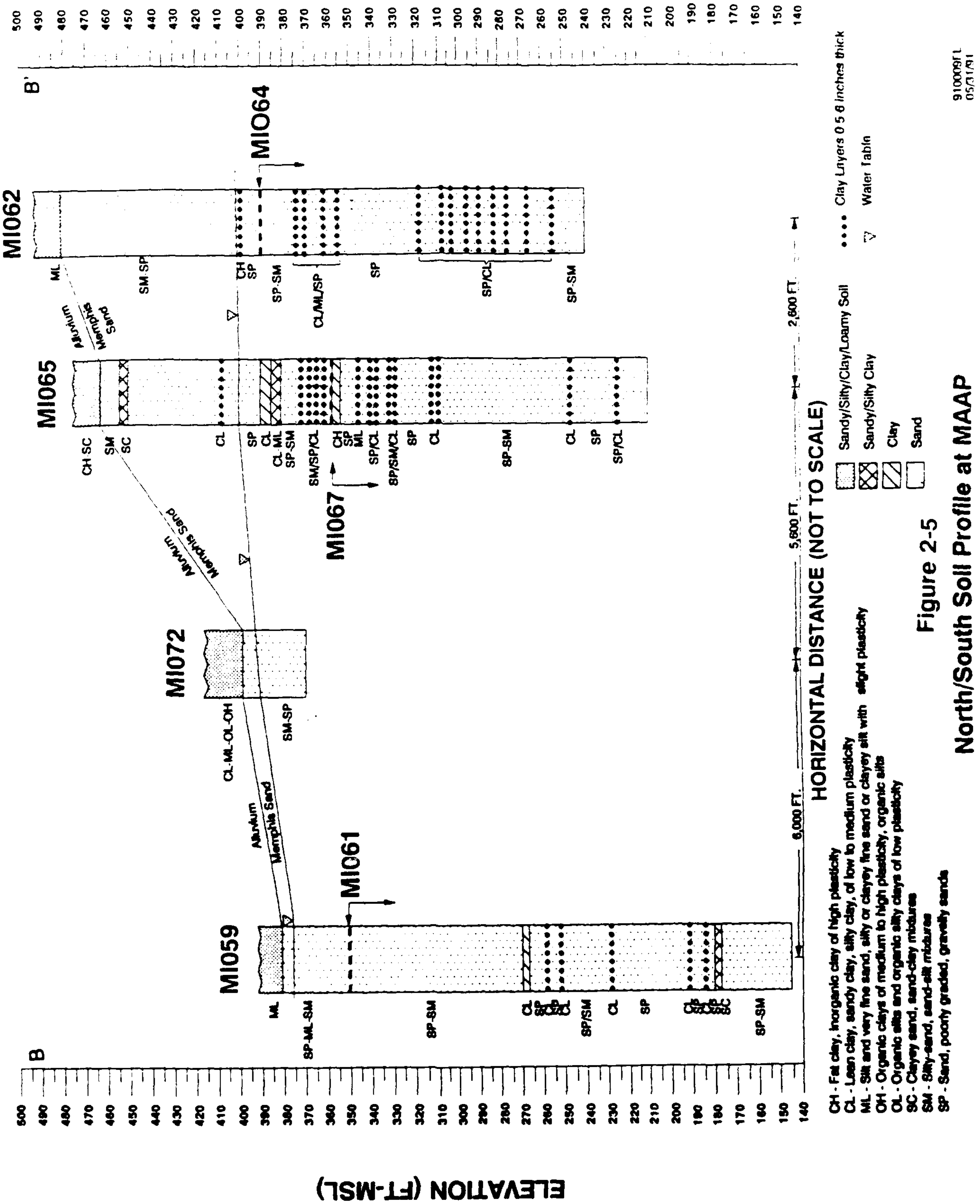
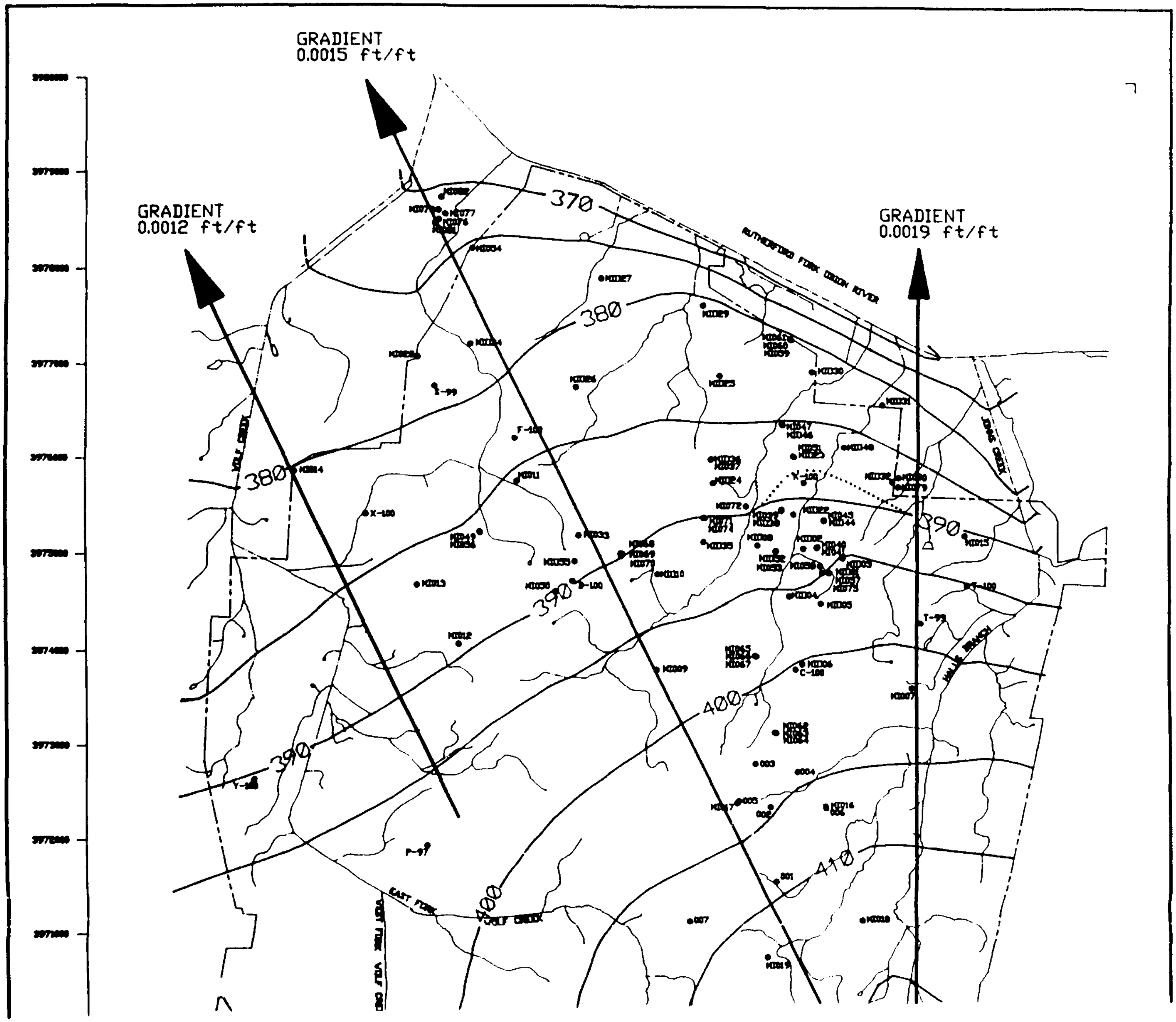
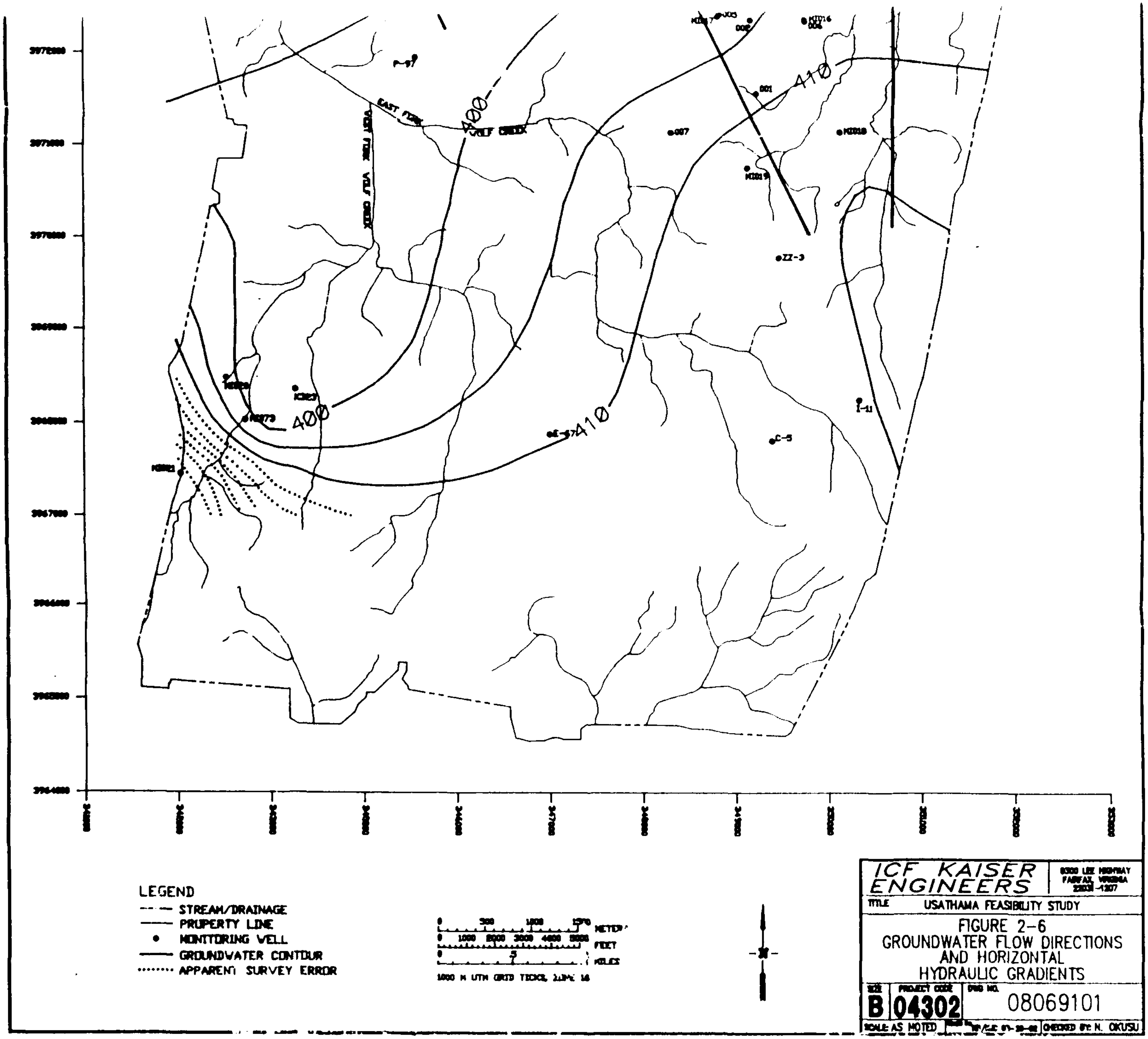


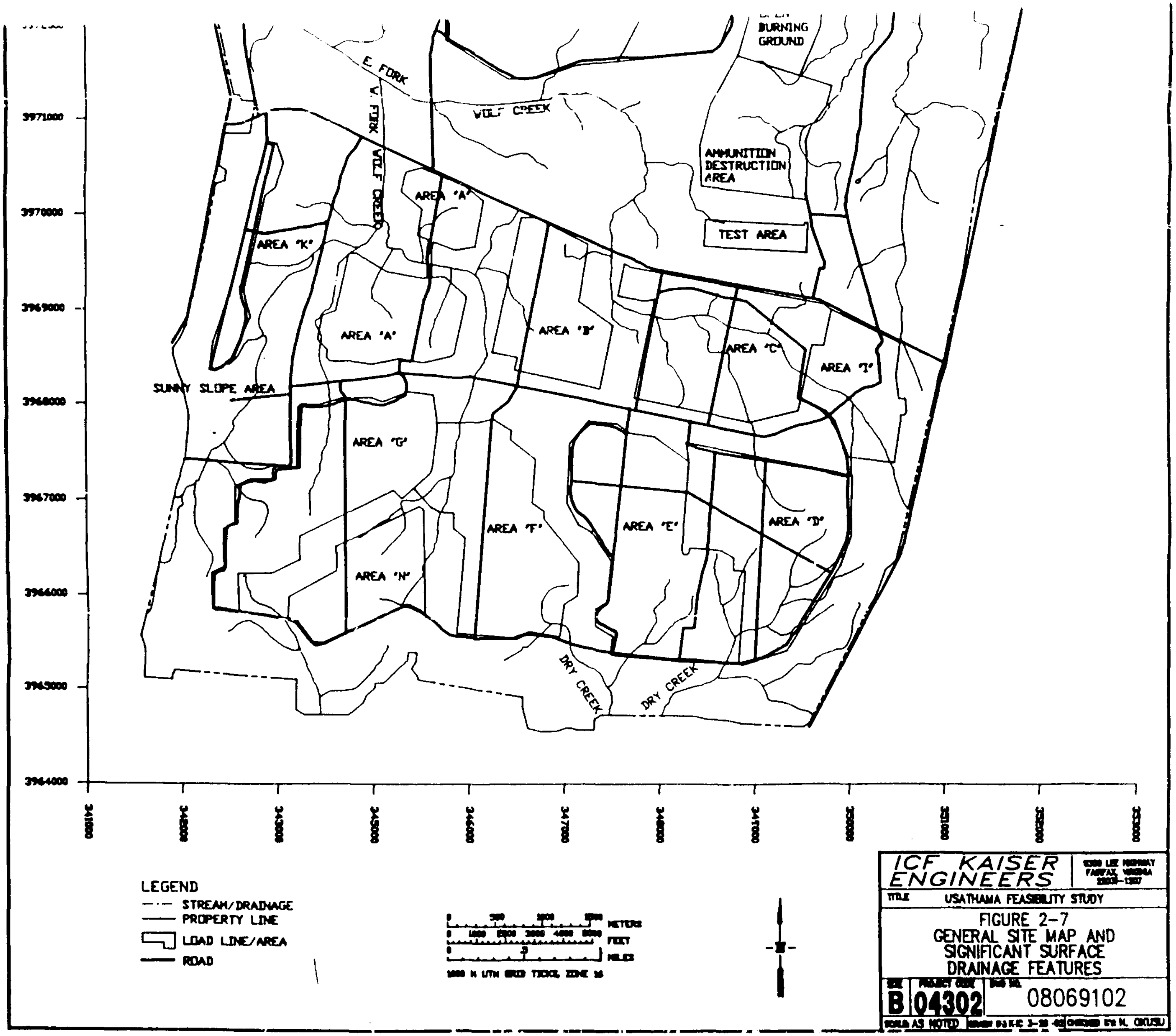
Figure 2-5
North/South Soil Profile at MAAP


GRADIENT
0.0015 ft/ft
GRADIENT
0.0012 ft/ft
GRADIENT
0.0019 ft/ft
370
380
380
390
390
390
400
400
410
RUTHERFORD FORK OBION RIVER
WOLF CREEK
EAST FORK
JOHNS CREEK



EAST FORK
WOLF CREEK
WEST FORK WOLF CREEK
400
410
ZZ-3
C-5
I-11
007
001
LEGEND
STREAM/DRAINAGE
PROPERTY LINE
MONITORING WELL
GROUNDWATER CONTOUR
APPARENT SURVEY ERROR
METERS
FEET
MILES
ICF KAISER ENGINEERS
USATHAMA FEASIBILITY STUDY
FIGURE 2-6
GROUNDWATER FLOW DIRECTIONS
AND HORIZONTAL
HYDRAULIC GRADIENTS
B
04302
08069101
SCALE: AS NOTED
CHECKED BY: N. OKUSU


LAVINIA AIRPORT ROAD
JOHNS CREEK
RUTHERFORD FORK OBION RIVER
104
AREA "Y"
"D" LINE PONDS (CLOSED)
LINE "C"
LINE "D"
DITCH 8
DITCH 6
DITCH 5
DITCH 4
OPEN BURNING GROUND
AREA "L"
AREA "P"
AREA "R"
AREA "N"
LINE "H"
LINE "E"
LINE "G"
LINE "F"
LINE "Z"
LINE "B"
LINE "V"
LINE "A"
LINE "X"
WOLF CREEK
E. FORK
W. FORK
3980000
3979000
3978000
3977000
3976000
3975000
3974000
3973000
3972000
3971000



ICF KAISER ENGINEERS

TITLE USATHAMA FEASIBILITY STUDY

FIGURE 2-7
GENERAL SITE MAP AND SIGNIFICANT SURFACE DRAINAGE FEATURES

SIZE B | PROJECT CODE 04302 | DWG NO. 08069102

SCALE AS NOTED | CHECKED BY N. OKUSU

It was observed during the surface water and sediment sampling conducted during the RI that the interior drainage ditches are "losing" ditches; that is, the base flow is zero. Surface water flow occurs only as a result of storm water runoff and pink water treatment facility (PWTF) discharge, and surface water recharges groundwater at these times. Since the ditches have been used and are currently used for the discharge of explosive-contaminated wastewater, an effort was made during the RI to characterize the ditch system near O-Line.

Stream gages were installed in four of the ditches in the vicinity of the O-Line Ponds area and flow measurements were taken during storm events. Analysis of these data indicated that during storms, between 50% and 90% of the total rainfall infiltrates the soil and the remaining 50% to 10% runs off to the ditches. It was estimated that 90% of the water which runs off to the ditches infiltrates the ditch floor while the remaining 10% flows through the ditch system as surface water (USATHAMA, 1991c).

These results indicate that the contaminated groundwater emanating from the O-Line Ponds area does not have the potential to impact surface water quality in the drainage ditches. However, analysis of the groundwater potential data indicates that some fraction of the groundwater probably discharges to the Rutherford Fork of the Obion River, Wolf Creek, and Johns Creek.

Based on a computer model developed for the site during the RI which calculates both potential and actual evapotranspiration, it was estimated that roughly 50% of the rainfall is evapotranspired to the atmosphere. Therefore, annual groundwater recharge is approximately 24 inches per year.

2.1.7 <u>Site Hydrogeology</u>

Sands in the Claiborne and Wilcox Group are the principal sources of groundwater in western Tennessee. At MAAP, the Memphis Sand of the Claiborne Group is the major aquifer. Although groundwater is also abundant in the underlying Cretaceous sediments (i.e., McNairy Sands), it has not been necessary to tap these deeper sources in most areas. The major controls on groundwater movement in this unconfined aquifer are the dip of the sediments, surface topography, and surface recharge and discharge patterns. Groundwater flow in the MAAP area is generally to the west, in the direction of regional dip of these sands, and also trends northerly because of the topographic influence. The gradient of the sands is estimated to be about 20 feet/mile to the northwest. On a general scale, there are no abrupt hydrologic boundaries in the aquifer. The formation is recognized as sand with clay lenses and clay rich zones which may locally alter vertical groundwater flow, and stratification of the sediments tends to make vertical conductivities lower than horizontal conductivities. The sands range from fine to very coarse-grained, and the grain size may vary both horizontally and vertically over short distances.

The clay units that dominate the stratigraphic section below the Wilcox Group to the top of the Cretaceous McNairy Sand are known as the Porters Creek Clay, the Clayton Formation, and the Owl Creek Formation. Collectively, these formations constitute a stratigraphic unit which is approximately 425 feet thick and begins approximately 250 feet below the surface at MAAP. The McNairy Sand is the artesian aquifer that underlies the installation and begins approximately 400 feet below the Claiborne Group. The McNairy Sand is approximately 200 feet thick near the Tennessee-Mississippi state line and contains cross-bedded, variegated sands with lenses and interbeds of clay and lignite (Cushing et al., 1964). Clays are common in the McNairy Sand and relatively large clay bodies occur stratigraphically near the middle of the formation (Parks and Russell, 1975).

The unconfined, unconsolidated aquifer beneath the MAAP site was further characterized by the installation of 26 new monitoring wells and numerous soil borings between July and December, 1990. The following information was used to refine the existing conceptual hydrogeologic model for the site developed by previous investigations (USATHAMA, 1982a, 1982b, 1983a):

(1) The aquifer at MAAP is a thick, laterally continuous, and highly transmissive hydrogeologic unit. The shallow portion of this aquifer is hydraulically connected to major streams and rivers in the area. Flow conditions in the deeper portion of the aquifer have not been fully characterized.

(2) The bottom elevation of the aquifer is inferred from the geologic log of MI061. A gray clay was encountered in this well at a depth of 265 feet. This depth corresponds well with published information regarding the elevation of the top of the Flour Island Formation, which is a thick continuous clay that acts as a regional confining unit for the Fort Pillow Sand of the Wilcox Group.

(3) Thin lenses of clay, silt, and clay-rich material are present throughout the aquifer horizon. The average thickness of these lenses appears to be approximately 0.2 ft. The lenses encountered during drilling ranged from 0.04 to 0.5 ft in thickness. Individual clay layers cannot be correlated between wells, and therefore, are considered discontinuous. These lenses are believed to impede the localized downward flow of groundwater without significant effect on horizontal movement or large-scale (regional) vertical migration.

(4) Within sandy intervals the aquifer material is highly stratified. This causes a reduction in vertical hydraulic conductivity, and contributes to anisotropic flow conditions in the aquifer.

2.1.7.1 Estimate of Hydraulic Conductivity. Estimates of hydraulic conductivity were calculated from slug tests, recovery tests, and grain size analysis of soil samples performed during the RI. Good agreement was obtained between hydraulic conductivity values calculated from these methods. These values also agreed well with the results of a pump test of a production well in Milan, TN, reported in a USGS publication (Parks and Carmichael, 1990). The resulting average hydraulic conductivity value is 27 ft/day.

2.1.7.2 Groundwater Flow Direction and Hydraulic Gradient. Water levels were measured in the monitoring wells on December 3, 1990. Groundwater contours for the aquifer beneath the site are shown in Figure 2-6. Water levels are highest in the southern half of the site, including elevations of 446 feet above mean sea level (ft-msl) in MI021 and 412 ft-msl in MI018. The water table elevation decreases in the northern portion of the site, toward the Rutherford Fork of the Obion River, which is consistent with a decrease in ground surface elevations. In monitoring well MI059, approximately 2,000 feet south of the river, the water table elevation is 379 ft-msl. The elevation of the river directly north of MI059 is approximately 370 ft-msl.

Groundwater flows in a direction perpendicular to groundwater contours lines, such that groundwater pathlines follow the most direct route from the recharge area to the discharge area. The change in hydraulic head (Δh) over a given distance (ΔL) is the hydraulic gradient ($\Delta h/\Delta L = i$) which drives the flow of water. The pathlines shown in Figure 2-6 illustrate the general flow directions for groundwater beneath MAAP. Groundwater is recharged primarily by precipitation infiltration in highland areas in the southern portion of the site, and discharges to the Rutherford Fork of the Obion River. Groundwater also discharges to the lower reaches of Wolf Creek and Johns Creeks where they flow into the Obion River. It is evident from the relationships between elevations of the ground surface, the water table, and the stream surface that the aquifer is contributing flow to the surface water bodies. However, given the vertical extent of the aquifer, it is likely that only the shallow portion of the aquifer is discharging to the surface water bodies while deeper portions of the aquifer flow toward regional discharge areas. This partitioning of thick, unconfined aquifers into shallow, intermediate, and deep flow systems is a common occurrence (Toth, 1963). In such settings, local topographic features control flow in the shallowest part of the aquifer while the deeper flow system is influenced by regional controls. The partitioning of flow within the aquifer at MAAP can only be inferred from the available data. However, regional studies have shown that shallow, intermediate, and deep flow systems occur within the Claiborne Group (Grubb, 1986).

Well clusters installed at the site allowed for the characterization of vertical groundwater gradients. Water levels measured in December 1990 show the presence of both upward and downward vertical gradients which range between +0.002 ft/ft to -0.004 ft/ft. The observed vertical gradients vary between well cluster locations, and are apparently unrelated to possible discharge effects imposed by the river. The differences in magnitude of vertical gradients may be a result of local stratification within the aquifer material. Nonetheless, the downward vertical gradients observed in some areas, and particularly near the Rutherford Fork, imply that groundwater beneath the site is moving downward within the Claiborne Group and much of the groundwater is not discharging to the Rutherford Fork. The downward flow of groundwater at the site is consistent with the findings of a regional aquifer study (Grubb, 1986).

2.1.7.3 Groundwater Velocity. From the O-Line Ponds area, groundwater flows toward the north-northwest. The horizontal hydraulic gradient, based on the water level data, is 0.0015 ft/ft. Assuming that the specific yield of the aquifer is approximately 20% (an average value for this aquifer material), the average groundwater flow velocity is 0.20 ft/day. It is important to note that this value for velocity represents an average velocity for this flow path, and that some variation is expected for various areas of the site.

2.2 SITE OPERATIONS AND HISTORY

The initial construction of the installation now known as MAAP was completed in January 1942 and the plant has operated continuously since that time. Currently, MAAP is a government-owned, contractor-operated (GOCO) military industrial installation under the jurisdiction of the Commanding General, Headquarters, United States Army Armament, Munitions and Chemical Command. Presently, MAAP is under the local command of the U.S. Army Ordnance Corps and is operated by Martin Marietta Ordnance Systems, Inc. The current level of employment at MAAP is 1,600 workers.

The general mission of MAAP currently includes:

a. The loading, assembling, and packaging (LAP) of conventional ammunition items as assigned;

b. Operation and maintenance, as directed, of active facilities in support of current operations;

c. Maintenance and/or layaway, in accordance with regulations for standby facilities, including any machinery and packaged items received from industry, in such condition as will permit rehabilitation and resumption of production within the time limitations prescribed;

d. Receipt, surveillance, maintenance, renovation, demilitarization, salvage, storage, and issue of assigned Field Service stocks and V and W Group items of industrial stocks as required or directed; and

e. Procurement, receipt, storage, and issue of necessary supplies, equipment, components, and essential materials.

2.2.1 MAAP Operations

MAAP facilities include thirteen active and inactive ammunition LAP Lines; one washout/rework line; one experimental line; one central x-ray facility; one test area; two shop maintenance areas; two magazine storage areas; 12 aboveground, earth-covered igloo magazine storage areas; a demolition and burning ground area; an administrative area; a family housing area; and recreational facilities. In addition,

there are medical facilities, fire/ambulance stations, 10 high pressure heating/process steam plants, 16 low-pressure heating plants, and 6 PWTFs. There are two sewage treatment plants located on the facility: Wolf Creek Ordnance Plant (WCOP) treatment plant in the northern portion of the site and Milan Ordnance Depot (MOD) sewage treatment plant in the south. A laundry facility for clothing used by on-site personnel while working with explosives/propellants is located in Area J. Located in K-Line is a coal-fired steam plant, a coal pile, a storage pond, and a treatment plant for coal pile runoff.

Approximately 13,600 acres within the MAAP boundary are leased for agricultural use. Approximately 3,984 acres are used as cropland. Cotton, corn, and soybean are the main crops, and smaller amounts of grain sorghum and wheat are also grown. In 1991, there were 2,851 head of cattle grazing on the facility. The cattle graze between April and November on about 8,700 acres. In addition, MAAP has more than 6,000 acres of managed timberland.

MAAP has 15 water supply wells that obtain water from the Memphis Sand. Four of the water-supply wells (C-5, I-11, S-99, and T-99) are currently in use as potable water sources. Wells C-5 and I-11 supply potable water to the southern portion of the site while T-99 and S-99, which are high-capacity, recently-installed wells, supply both potable water and production water to the northern portion of the site. All wells which supply potable water have water treatment equipment associated with them. The facility adds caustic soda to raise the pH of the water to 7 pH units (the pH of the groundwater underlying the site ranges from 5 to 6 pH units), phosphate for corrosion control, and chlorine for disinfection purposes. Typically, a primary well and a secondary well are designated within each well pair. The primary well is pumped for several months and the secondary well is used only when necessary to meet demand.

Wells F-100 and T-100 are active but are not currently being used. These wells are maintained for usage should the plant's potable water demands increase in the future. Wells E-67, K-323, ZZ-3, and Y-100 are used for the following non-potable purposes: fire prevention, cooling water, production, and restrooms. Well P-97 is the non-potable water-supply well for an inactive building, so it is not currently used. Wells X-100, B-100, C-100, and K-100 are not used because the water is contaminated with explosives. (Personal communications, Mike Harris and Bill Blaylock, Martin Marietta, April 10 and April 19, 1991.) The depths of the above-listed water supply wells range from 141 to 292 feet.

Of the 13 process areas active by the end of World War II, only 7 lines (A, B, D, H, O, V, and X) are in use today. In the past, wastewater from various production activities in the lines was discharged to open ditches that drained from sumps or surface impoundments into both intermittent and perennial streams and rivers. Currently, MAAP treats all process water from the lines that generate explosives-contaminated wastewater in the six PWTFs. This wastewater is processed by an activated carbon adsorption system and discharged under the authority of a National Pollutant Discharge Elimination System (NPDES) permit.

2.2.2 O-Line Ponds Area

From about 1942 until 1978, wastewater from O-Line, the munitions demilitarization facility, was discharged to 11 unlined settling ponds (i.e., the O-Line Ponds). In December 1984, the O-Line Ponds were closed with a multilayered cap. However, in May 1984, because of the level of contamination in the groundwater, the facility was proposed for listing on the National Priorities List (NPL). Final listing on the NPL took place in August 1987.

The O-Line area (Figure 2-8) at MAAP was built as part of the initial plant construction activity in 1941. It has operated since 1942 as an ordnance demilitarization facility. From the start, the major function of the line has been to remove explosives from bombs and projectiles by injecting a high-pressure stream of hot water and steam into the steel shell of the munitions. The types of explosives handled in the facility included 2,4,6-TNT and RDX.

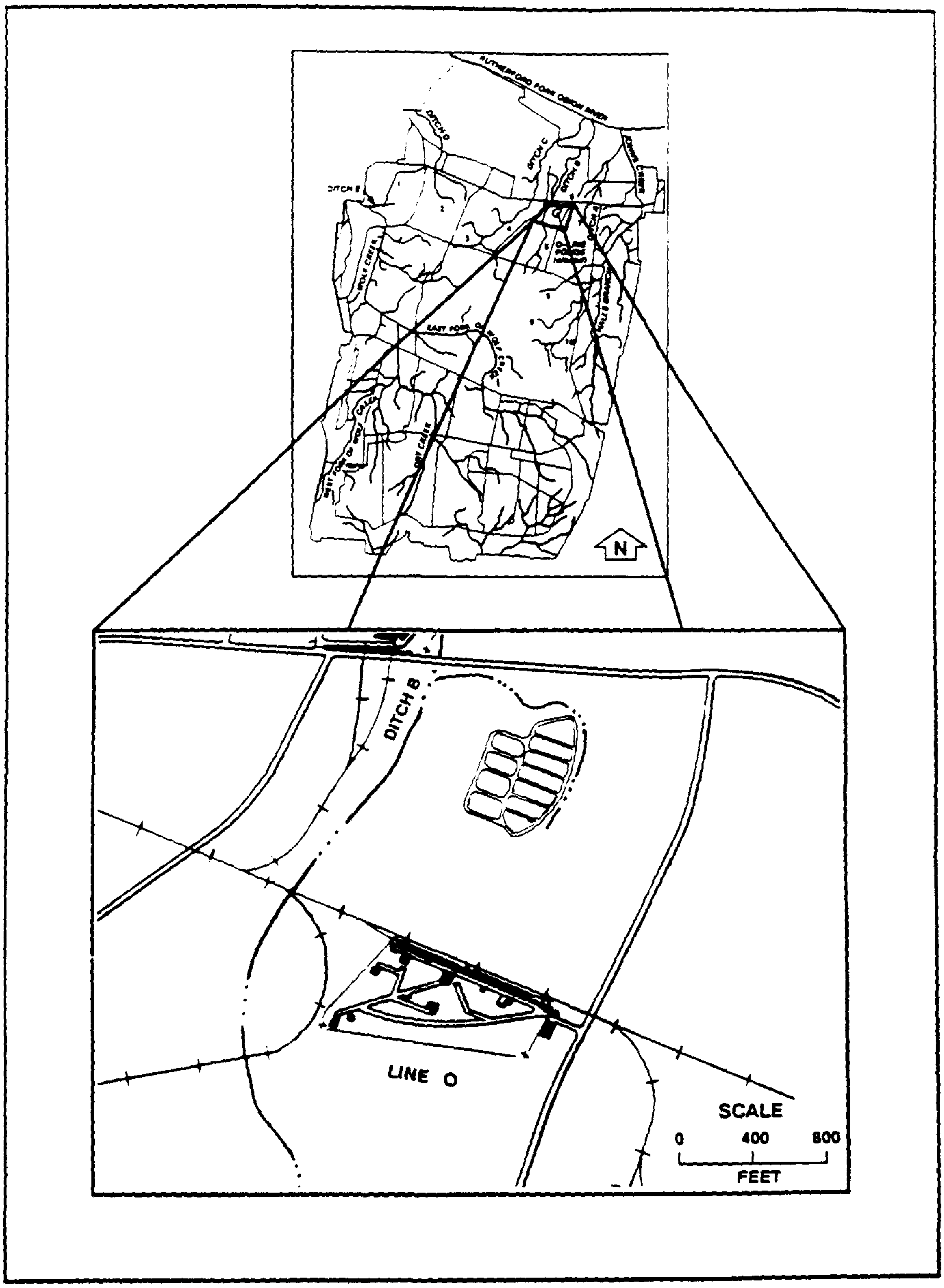


Figure 2-8
O-Line and O-Line Ponds Location

Wastewater contaminated with explosives was discharged from the O-Line washout operations through a series of baffled concrete sumps where cooling caused significant amounts of explosives to precipitate out of the waste stream. The collected explosives were periodically removed from the sumps and burned at the burning ground. Effluent from the sumps was initially discharged to an open ditch known as Ditch B (Figure 2-8), which ran through the O-Line area. At an as yet undetermined date in 1942, 11 individual surface impoundments were excavated to receive the O-Line effluent before discharge to the open ditch. The ponds (Figure 2-9) reportedly were excavated into native soil and the excavated material was used to form the pond dikes.

The ponds were 3-5 feet deep, had a total capacity of 5.5 million gallons, and covered an area of about 280,000 square feet (USATHAMA, 1982). The ponds were interconnected with a series of spillways, open ditches, and distribution boxes allowing several pond configurations to be used in series. Effluent from the last pond flowed through a bank of sawdust-filled tanks before discharge to Ditch B. The sawdust from the tanks was periodically removed and burned in the Open Burning Ground (OBG). The drainage ditch that received effluent from the final pond discharged to the Rutherford Fork of the Obion River which runs along the northern boundary of MAAP as shown in Figure 2-8.

In 1971, solids in the ponds were dredged and placed in the northwestern corner of the pond area. An attempt was made to burn these materials in the Open Burning Ground but it was determined that these materials would not burn.

In 1978, USATHAMA conducted an Installation Assessment of MAAP. This study consisted of a records search and interviews with employees. It was reported in this document that between 300 to 500 pounds of explosives could be washed out in an 8-hour shift, and that many types of explosive materials were handled in this area. It was also reported that at the time of the survey, all of the wastewater ponds were full and signs of overflow were obvious. The overflow entered the open ditch near O-Line.

Also in 1978, the U.S. Army Environmental Hygiene Agency's (USAEHA) water well sampling program (USAEHA, 1978) revealed that three of MAAP's 11 water supply wells were contaminated with explosive constituents. The affected wells were near a number of production areas, including O-Line.

MAAP facility personnel elected to cease using the O-Line Ponds since they were determined to be the most likely source of the groundwater contamination. As a result, the O-Line operation was placed in a standby status in December 1978, and effluent has not been discharged to the ponds since that time. The impounded effluent remained in the ponds until 1981, when the supernatant was pumped out and treated in a newly constructed PWTF, consisting primarily of carbon adsorption units and fabric filtration units. The effluent from the PWTF was discharged to the open ditch under the facility's NPDES permit. A PVC liner was placed on top of the pond sediments in 1981 and the liner was filled with fresh water to stabilize it.

MAAP subsequently prepared and submitted a RCRA closure plan for the pond site (USATHAMA, 1982b). The closure plan was approved by the Tennessee Department of Health and the Environment (TDHE) and implemented in 1984. The closure plan called for the construction of a multilayered cover system for the ponds. The water in the ponds was tested and discharged under the MAAP NPDES permit. The ponds were then filled with clean inorganic fill from an on-site borrow pit. The fill was placed in 2-foot lifts and compacted. The pond berms were graded to accommodate the final grade, and the perimeter of the fill material was extended to the outer boundary of the O-Line Pond berms. A clay layer was placed in 6-inch lifts and compacted under optimum moisture conditions to achieve maximum soil density. The clay layer consisted of five lifts for a total of 30 inches. The perimeter of the clay layer was keyed into the existing subsurface by tying into a 3 feet wide by 8 feet deep trench of clay compacted in 2-foot lifts up to ground level. The clay layer was topped with an 8-inch gravel layer that contained a

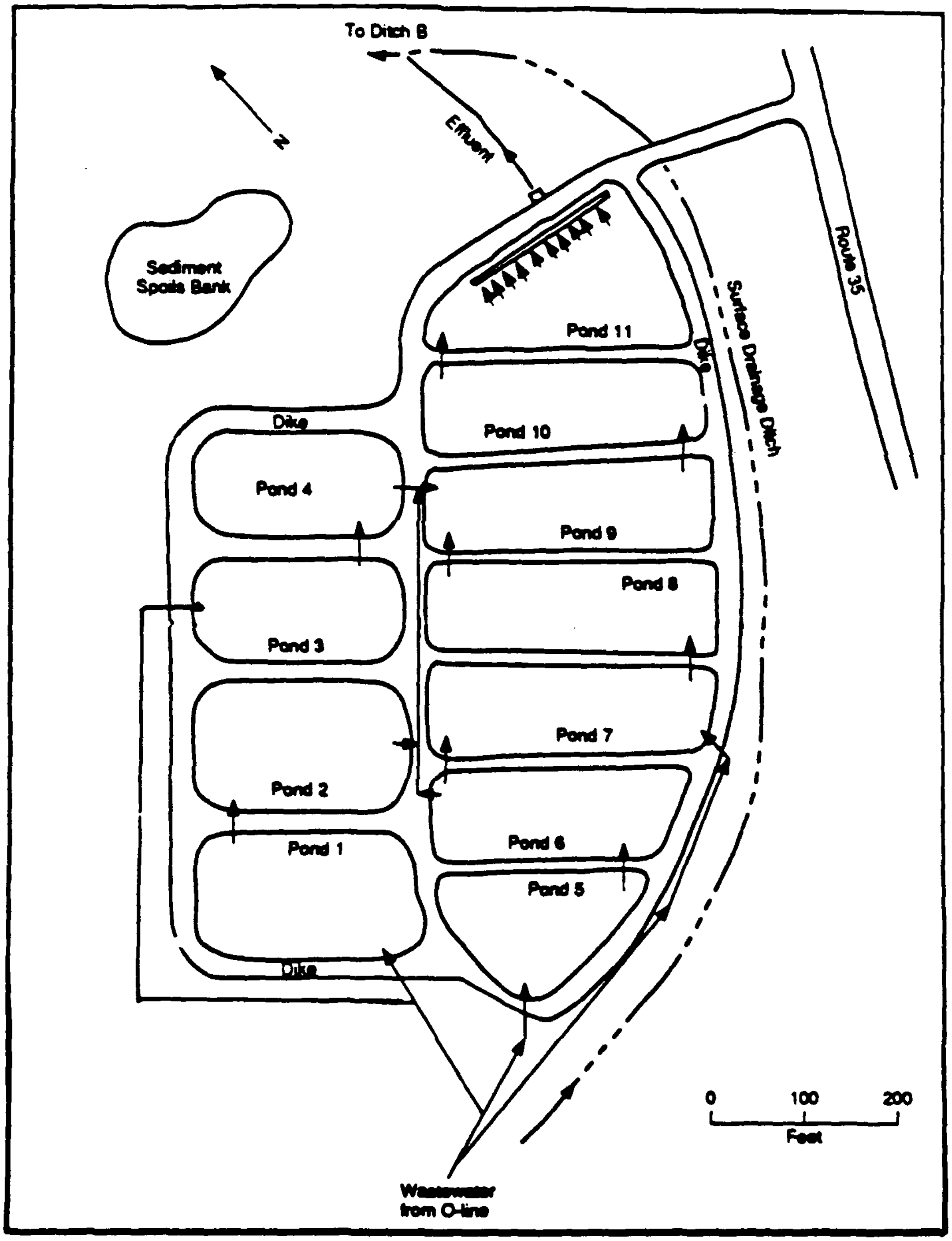


Figure 2-9
O-Line Ponds Area

4-inch perforated PVC pipe perimeter drainage system. The gravel layer was covered with 12 inches of clay and 6 inches of topsoil consistent with the final grade. A vegetative cover was then established. A cross section (Line A--A') of the multilayered cover system is depicted in Figure 2-10.

The rationale for taking the ponds out of service and placing the liner on top of the contaminated soil was to decrease hydraulic loading on the source. The cap was designed to further minimize hydraulic loading on the contamination source by providing a multilayered system. Rates of percolation through the upper soils of the cap were determined using the Hydrologic Simulation on Solid Waste Disposal Sites (HSSWDS) Model developed by the Corps of Engineers. The thickness of the drain layer was determined by calculating the maximum height of water expected in the layer with a final grade slope of 3%. The maximum height of water expected is 2.63 inches. To be conservatively safe, an 8-inch drain layer was chosen.

The post-closure measures that have been performed since cap installation are summarized as follows:

- Periodic cutting of grass and spraying of turf to prevent excessive vegetation and deep root growth that may adversely affect cover performance; and
- Maintenance of fences that limit access to the site.

In addition, the facility has performed semiannual and then annual sampling of 11 existing wells downgradient of the O-Line Ponds area to monitor groundwater quality.

2.3 CONTAMINATION ASSESSMENT

The significant findings of the RI and previous investigations related to the nature and extent of contamination are summarized in this section.

2.3.1 Summary of Existing Pond Data

Only limited monitoring data are available for the effluent that was discharged from the O-Line operations area into the O-Line Ponds. MAAP representatives reported that in the past, 34,000 gallons per day of O-Line effluent was discharged. It was also indicated that before they were closed, the O-Line Ponds had received effluent containing up to 800 mg/L of total nitrobodies (personal communication, Bill Blaylock, Martin Marietta, November 1987, reported by USATHAMA, 1988).

The contaminant burden of the effluent that was discharged to the O-Line Ponds can also be inferred from present operations at O-Line. MAAP representatives have indicated to Argonne National Laboratory staff that analytical results for effluent from O-Line prior to the treatment plant are generally representative of effluent quality discharged to the O-Line Ponds before the PWTF was constructed (personal communication, Bill Blaylock, Martin Marietta, January 1988; reported by USATHAMA, 1988). Assuming that O-Line operations have remained generally unchanged since the installation of the PWTF, effluent water quality prior to treatment in the PWTF should be fairly representative of the effluent discharged to the O-Line Ponds in the past. Table 2-1 summarizes the nitrobody concentrations of O-Line effluent after a fabric filtration step in the PWTF for the period from October 14, 1985, through December 16, 1986. As indicated in this table, the total nitrobody concentration of effluent for the period of record ranged from 1.92 to 10.82 mg/L. This information suggests that the 800 mg/L total nitrobody content reported for the O-Line effluent was the exception rather than the rule.

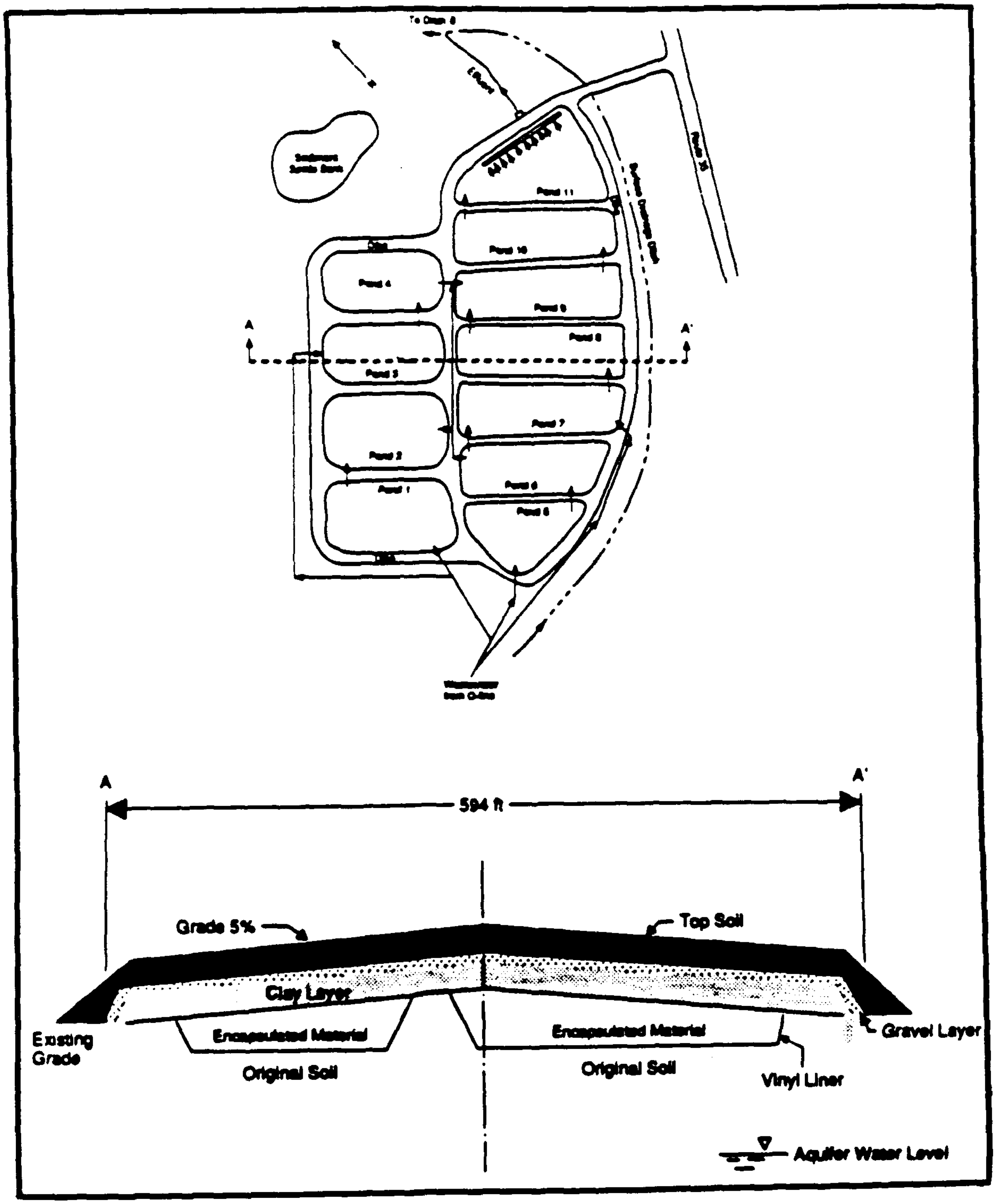


Figure 2-10
Cross-Sectional Sketch of the Multilayered Cover System Used for the O-Line Ponds

TABLE 2-1
NITROBODY[a] CONCENTRATIONS IN O-LINE EFFLUENT AFTER FABRIC FILTRATION

Sample Date	Concentration (mg/L)	Sample Date	Concentration (mg/L)
1985		1986 (Cont'd)	
Oct. 14	4.21	Sept. 19	3.59
Oct. 16	4.19	Sept. 22	3.61
Oct. 17	4.0	Sept. 26	3.46
Oct. 18	10.45	Oct. 2	3.36
Oct. 23	4.1	Oct. 8	7.04
Oct. 28	5.24	Oct. 10	3.75
Nov. 12	4.0	Oct. 13	3.48
		Oct. 14	3.92
1986		Oct. 15	3.17
June 4	5.31	Oct. 20	1.92
June 11	5.20	Oct. 22	4.70
June 23	7.31	Oct. 30	5.88
June 27	8.66	Nov. 3	6.98
July 7	7.18	Nov. 6	6.65
July 18	7.16	Nov. 10	3.34
July 28	5.40	Nov. 11	4.65
Aug. 1	6.0	Nov. 14	4.64
Aug. 6	4.07	Nov. 17	5.24
Aug. 11	4.16	Nov. 18	4.89
Aug. 21	4.09	Nov. 24	4.87
Aug. 25	3.4	Dec. 1	3.00
Sept. 4	3.22	Dec. 12	9.72
Sept. 12	3.25	Dec. 16	10.82
Sept. 17	5.37		

[a] Nitrobodies are nitrogen-containing, explosives-related chemicals such as TNT, DNT, RDX, and HMX.

Source: USATHAMA, 1988

The sediment and supernatant in the O-Line Ponds were sampled and analyzed before the ponds were closed (USATHAMA 1982a, 1981). In 1980, pond and spoil-bank samples were collected and analyzed for priority pollutant inorganic compounds and explosive contaminants, including 2,4,6-TNT, RDX, 2,6-DNT and 2,4-DNT (USATHAMA, 1982a). Pond supernatant samples were also analyzed for priority pollutant extractable compounds and volatile compounds while pond sediment samples were analyzed for priority pollutant extractable compounds only. The samples for both supernatant and sediment were collected from the approximate centers of Ponds 1, 3, 5, 8, and 11.

Table 2-2 shows that explosives were detected in water and sediment samples at high levels in Ponds 1 and 5, which are primary receiving ponds. Pond 5 contained the highest concentrations of total nitrobodies (4,820 μg/L in the supernatant and 49.5 mg/kg in the sediment). The samples collected from Pond 11, which was the final settling pond before discharge to the ditch, had the lowest concentration of nitrobodies (0.3 μg/L in the supernatant and 4.16 mg/kg in the sediment). All pond samples contained detectable concentrations of each of the explosive constituents RDX, 2,4,6-TNT, 2,4-DNT, and 2,6-DNT.

Although lead and chromium were not detected in the pond water samples, the laboratory's method detection limits for these analytes (116 and 133 μg/L, respectively) are higher than their respective MCLs (50 and 100 μg/L) and their respective State surface water criteria (33.8 and 100 μg/L). Therefore, inorganic compounds may be contaminants of concern in this area.

Water quality parameters such as nitrate, nitrite, and phosphate were detected in the pond water at approximately the same levels as they were detected in stream water and groundwater samples.

Table 2-3 presents the volatile organic compounds (VOCs) and semivolatile organic compounds detected in the pond water samples and composite sediment samples. Methylene chloride, chloroform, and benzene (tentatively identified) were detected in the water samples. Dibutyl phthalate, diethyl phthalate, and bis(2-ethylhexyl) phthalate were also detected in the water samples. High levels of phthalates were detected in the composite sediment samples (0.033% and 0.066% total phthalates by weight in soil). The report states that the gradual reduction in bis(2-ethylhexyl) phthalate from ponds 5 to 8 to 11 indicates that this contaminant may have been introduced by the O-Line wastewater into the first pond of the series. These results indicate that VOCs and semivolatile organic compounds are probably contaminants of concern in the ponds.

In 1981, extensive pond sampling and analysis efforts were conducted as part of a leaching test study on the O-Line Pond sediments (USATHAMA, 1981). Surficial and core sediment samples were collected from multiple locations in each of the 11 ponds (Figure 2-11). A subset of the samples was analyzed for 2,4,6-TNT, 2,4-DNT, 2,6-DNT, RDX, lead, chromium, mercury, cadmium, and reactivity. Additional sediment samples were subjected to a leachate generation test. The leachate was subsequently analyzed for the principal explosive constituents.

Table 2-4 presents the data from analysis of the surficial pond sediment samples. The two DNT compounds were not detected or were present only in trace concentrations in these samples. RDX and TNT were detected in nearly all of the samples collected. Concentrations of RDX range from 1.18 to 1,340 mg/kg, and TNT concentrations ranged from undetected to 75,100 mg/kg. The higher concentrations of RDX and TNT were in samples from Ponds 1, 3, 5, 6, and 7.

Table 2-5 summarizes the analyses of core sediment samples. Concentrations of RDX and TNT generally decrease with depth for all sample locations except in the case of the outlet location in Pond 5, where concentrations increased with depth.

TABLE 2-2
CONCENTRATIONS OF EXPLOSIVES AND INORGANICS IN O-LINE PONDS MEASURED IN 1980

Lagoon		Concentrations in Micrograms Per Liter (Water) and Milligrams Per Kilogram (Sediment)										
		TNT	2,4-DNT	2,6-DNT	RDX	Lead	Chromium	Mercury	Nitrate	Nitrite	Phosphate	Sulfate
1	Water	+	+	+	850	ND	ND	ND	2,000	68	280	+
	Sediment	13.00	.037	.085	26.0	7.1	27.5	ND	10.1	0.12	ND	31.0
3	Water	0.7	ND	+	+	ND	ND	ND	ND	7	280	+
	Sediment	11.00	.310	.083	4.70	20.2	22.5	ND	10.7	0.19	0.30	29.0
5	Water	65	ND	5.4	4,750	ND	ND	ND	2,600	30	40	+
	Sediment	10.50	.825	.023	38.0	22.6	22.5	ND	12.0	0.73	ND	72.0
8	Water	4.3	ND	+	+	ND	ND	ND	180	15	100	+
	Sediment	1.34	.022	.002	6.5	8.6	18.7	ND	11.6	0.19	ND	24.3
11	Water	0.3	ND	ND	+	ND	ND	ND	ND	7	70	+
	Sediment	0.50	.054	.006	3.6	8.6	21.3	ND	ND	0.19	0.30	21.1
Spoils Bank	Sediment	7.5	.031	.017	36.1	11.1	21.9	ND	22.1	0.57	ND	67.1
Detection Limits	Water	*	*	*	*	116	133	0.117	90.9	7	160	*
	Sediment	*	*	*	*	3 [illegible]	4 [illegible]	0.067	0.28	0.04	0.30	11.6

NOTES: Explosives determinations by GC-EC. RDX determinations in sediment not corrected for method recovery efficiency.

* Explosives detection limits are variable depending on sample source.
ND Analyte not detected.
\+ Analyte observed at a level below the calculated detection limit at the 90% confidence level.

SOURCE: USATHAMA, 1982.

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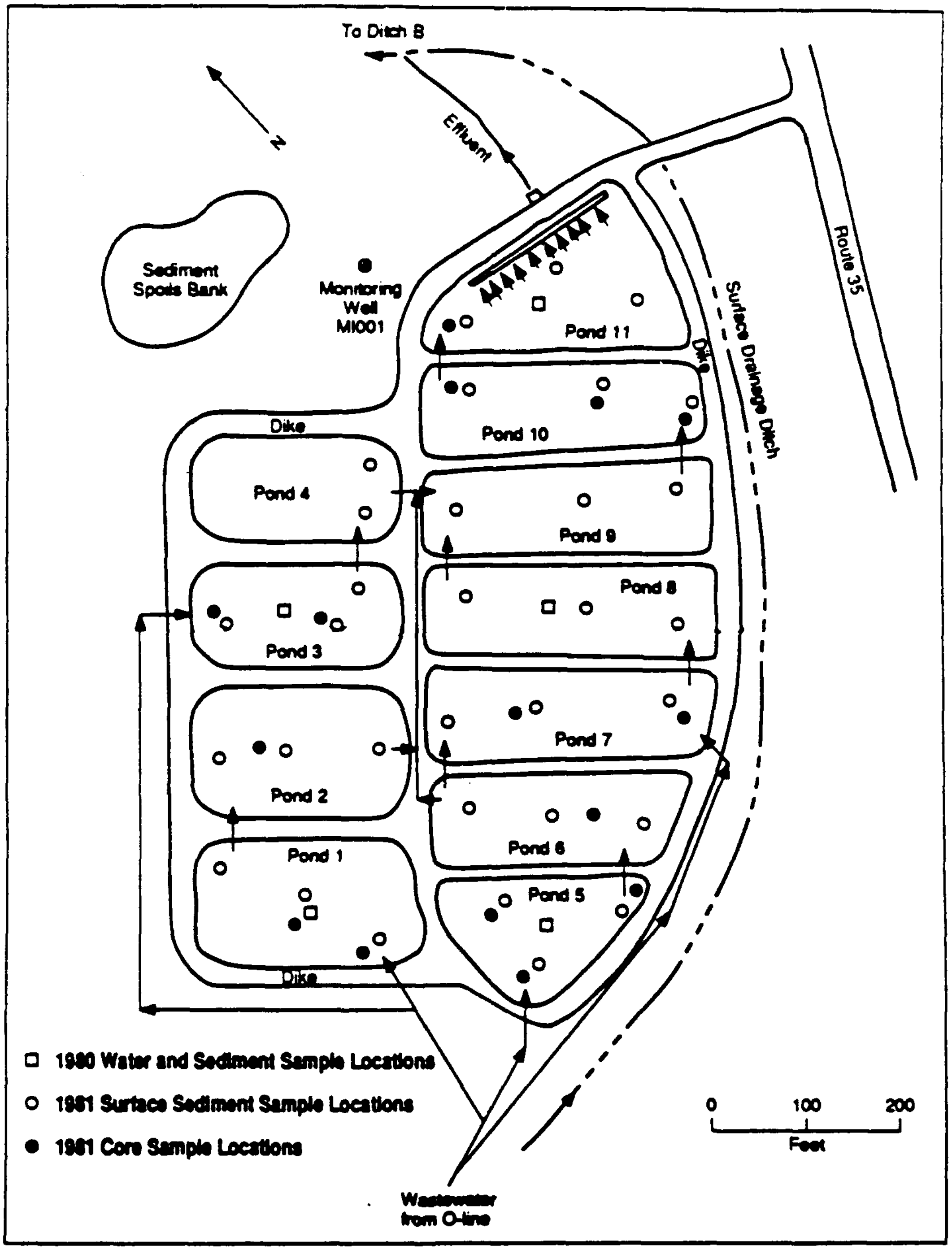
TABLE 2-3
CONCENTRATIONS OF ORGANIC COMPOUNDS IN O-LINE PONDS SAMPLES MEASURED IN 1980

Analyte	Water Samples (µg/L) Pond Number					Composite Sediment Samples* (µg/g)	
	1	3	5	8	11	1,3	5,8,11
Methylene Chloride	110	37	100	210	30		
Freon	X		X				
Pentane	X	X	X	X	X		
Hexane	X	X	X	X	X		
1,2-Diethoxyethane		X		X	X		
Chloroform				3	5		
Methyl cyclopentane				X			
2-Methyl pentane				X			
3-Methyl pentane				X			
2,3-Dimethyl butane				X			
Benzene				35**			
2,6-DNT	X					73	
2,4-DNT						220	820
TNT	X					X	X
Dinitrobenzene			X				
Dinitrophenol			X				
Trinitrobenzene			X			X	X
Diethyl/dimethyl phenol					**		
Nonyl phenol						X	
Phthalate Esters							
Dibutyl		3	2		X	1,500	1,400
Diethyl			X	5	X	110	
Bis(2-ethyl hexyl)	50	11	88	19	4	1,700	5,200
Butylbutoxyethyl		X			X	X	
t-2, t-6 Farnesyl Cyanide		X		X			
Esther-alcohols	X	X	X	X	X		

X Analyte identified but not quantified
blank Analyte not detected
* Sediment samples were not analyzed for volatile organic compounds
** Benzene and 2-methylpentane were reported as alternative identifiers of one small GC peak. The mass spectra fit 2-methylpentane more closely than benzene.

Source: USATHAMA, 1982



Sources: USATHAMA, 1981; USATHAMA, 1982a; USATHAMA, 1982b

Figure 2-11
Sample Locations in the O-Line Ponds

TABLE 2-4
ANALYSES OF SURFICIAL SEDIMENT SAMPLES FROM O-LINE PONDS IN 1981 (mg/kg)

Pond	Sample Location	2,4,6-TNT	RDX	Pb	Cr	Cd	Hg	2,4-DNT	2,6-DNT	Moisture Content (% wet. wt.)
1	Inlet	38,500	510	21	9	4.20	<0.18	<40.1	<73.3	38
	Outlet	28,200	504	28	14	<3.50	<0.21	<35.7	<65.2	31
2	Inlet	46.8	320	33	15	<3.50	<0.13	<3.10	<5.67	21
	Middle	42.7	531	24	16	<3.50	<0.12	<3.07	<5.60	20
	Outlet	10.5	259	16	13	<3.50	<0.12	<0.288	<0.527	15
3	Inlet	75,100	1,340	34	14	11.3	<0.17	<40.9	<74.7	40
	Middle	249	127	21	14	<3.50	<0.12	<2.47	<4.51	<0.7
	Outlet	114	303	26	17	<3.50	<0.12	<0.316	<0.578	20
4	Inlet	42.3	406	26	16	<3.50	<0.12	<3.08	<5.63	20
	Middle	11.2	424	31	18	<3.50	<0.13	<0.310	<0.567	21
	Outlet	17.1	384	27	17	<3.50	<0.12	<0.303	<0.553	19
5	Inlet	12,700	697	30	14	<3.50	<0.16	<34.3	<62.7	26
	Middle	2,080	624	24	19	<3.50	<0.15	<31.5	<57.6	21
	Outlet	305	427	20	12	<3.50	<0.16	<3.10	<5.67	21
6	Inlet	1,290	976	26	14	<3.50	<0.13	<33.6	<61.3	25
	Middle	74.2	437	37	21	<3.50	<0.13	<3.31	<6.05	26
	Outlet	16.4	612	30	15	<3.50	<0.13	<0.327	<0.597	25
7	Inlet	8.43	420	31	15	<3.50	<0.15	<0.299	<0.546	18
	Middle	736	424	36	18	<3.50	<0.14	<3.07	<5.60	20
	Outlet	2,320	430	23	12	<3.50	<0.15	<31.8	<58.2	23
8	Inlet	716	460	17	9	<3.50	<0.12	<3.03	<5.53	19
	Middle	12.8	178	34	18	<3.50	<0.12	<0.292	<0.533	16
	Outlet	3.40	331	39	17	<3.50	<0.13	<0.311	<0.568	20
9	Inlet	28.8	439	37	18	<3.50	<0.13	<3.18	<5.82	23
	Middle	6.54	325	35	16	<3.50	<0.12	<0.301	<0.549	18
	Outlet	15.7	454	28	15	<3.50	<0.12	<0.299	<0.546	18

TABLE 2-4 (Continued)
ANALYSES OF SURFICIAL SEDIMENT SAMPLES FROM O-LINE PONDS IN 1981 (mg/kg)

Pond	Sample Location	2,4,6-TNT	RDX	Pb	Cr	Cd	Hg	2,4-DNT	2,6-DNT	Moisture Content (% wet. wt.)
10	Inlet	9.98	380	34	17	<3.50	<0.12	<0.331	<0.605	20
	Middle	12.0	64.9	23	11	<3.50	<0.12	<0.322	<0.588	19
	Outlet	7.53	462	29	15	<3.50	<0.12	<0.307	<0.560	20
11	Inlet	<0.123	1.48	25	13	<3.50	<0.20	<0.288	<0.527	15
	Middle	0.250	1.18	27	12	<3.50	<0.13	<0.314	<0.574	22
	Outlet	0.167	67.3	33	16	<3.50	<0.12	<0.310	<0.567	21
Drainage Ditch	Surface	<0.134	2.80	42	17	<3.50	<0.12	<0.314	<0.574	22
	4-ft depth	13.2	16.9	24	10	<3.50	<0.12	<0.302	<0.552	18

[a] 'Less than' symbol (<) indicates that the concentration was below the analytical detection limit shown; except for drainage ditch samples, each sample consisted of a core of the top 6 in. of the pond sediment.

Source: USATHAMA, 198'

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Table 2-5
Analyses of Selected Core Sediment Samples from O-Line Ponds in 1981

Pond	Sample Location	Depth (in.)	Concentration (mg/kg) 2,4,6-TNT	RDX	Pb	Cr	Cd	Hg	2,4-DNT	2,6-DNT	Moisture Content (% wet wt.)
3	Middle	0-6	176	572	22	15	<4	<0.2	<3.070	<5.60	20
	Middle	30-36	109	131	16	10	<4	<0.2	<0.295	<0.540	17
	Inlet	0-6	38,800	734	24	10	5	<0.2	<43.0	<78.6	43
	Inlet	6-12	41,300	715	24	5	6	<0.2	<35.5	<64.9	31
	Inlet	18-24	691	263	18	9	<4	<0.2	<31.4	<57.4	22
	Inlet	30-36	534	80.7	20	9	<4	<0.6	<31.4	<57.4	21
5	Outlet	0-6	101	22.8	21	12	<4	<0.1	<0.303	<0.553	19
	Outlet	30-36	715	363	20	10	<4	<0.1	<24.7	<45.2	0.8
	Inlet	0-6	9,830	476	29	12	<4	<0.2	<33.1	<60.5	26
	Inlet	6-12	463	75.8	20	14	<4	<0.2	<3.17	<5.78	21
	Inlet	18-24	406	181	20	12	<4	<0.2	<3.06	<5.59	19
	Inlet	30-36	307	117	21	11	<4	<0.2	<3.02	<5.52	18
	Middle	0-6	449	498	19	10	<4	<0.3	<3.10	<5.67	21
	Middle	30-36	49.6	98.7	19	11	<4	<0.2	<0.295	<0.540	17
6	Middle	0-6	91.7	40.9	23	9	<4	<0.2	<0.345	<0.631	29
	Middle	24-30	12.9	34.2	22	12	<4	<0.2	<0.307	<0.561	17
7	Inlet	0-6	101	508	20	10	<4	<0.2	<0.318	<0.582	23
	Inlet	6-12	51.9	123	23	10	<4	<0.2	<0.310	<0.567	21
	Inlet	18-24	93.1	84.2	24	11	<4	<0.2	<0.303	<0.553	19
	Inlet	30-36	43.9	132	20	10	<4	<0.1	<0.302	<0.552	18
	Middle	0-6	7.64	324	24	10	<4	<0.1	<0.316	<0.578	17
	Middle	30-36	6.24	49.1	18	8	<4	<0.1	<0.295	<0.539	16

Note: 'Less than' symbol (<) indicates that the concentration was below the analytical detection limits shown.

Source: USATHAMA, 1981

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Many of the same samples listed in Table 2-5 were also used for the simulated leachate test. Deionized, organic-free water 10 times the volume of the sediment sample was continuously mixed with the sediment for 24 hours. The investigators determined that explosive contaminant levels in the leachate were relatively independent of pH. As a result, it was decided to focus on generating leachate under naturally occurring pH conditions with no pH control or adjustment. In the resulting tests, trace metals were present in the leachate but were below concentrations of regulatory concern. The two DNT compounds were not detected. Concentrations of RDX and TNT in the leachate samples generally corresponded to the total constituent analytical results for the sediments. Concentrations of TNT in the leachate ranged from 0.233 to 55.8 mg/L, and RDX concentrations ranged from 2.3 to 50.1 mg/L. Core samples from depths of 30-36 inches generated significant levels of explosives in the simulated leachate. These results suggest that although the ponds were drained before closure, the residual pond sediments represent a relatively significant source of contamination.

Two of the sediment samples were tested for reactivity by the U.S. Army Armament Research and Development Command (Kirshenbaum, 1982). The Pond 1 sample contained 3.8% 2,4,6-TNT and 0.05% RDX. The Pond 3 sample contained 7.5% 2,4,6-TNT and 0.1% RDX. The samples were dried, crushed, and sieved prior to analysis. It was determined that the Pond 1 sample was non-reactive. However, the Pond 3 sample was reactive because it exhibited an explosive reaction when heated under confinement. The report also concluded that if the sediments contain 20 to 25% moisture by weight, they will not explode if subjected to impact, nor will they sustain a detonation if subjected to shock.

2.3.2 Summary of Existing Groundwater Data

2.3.2.1 Previous Investigations. An Installation Assessment of MAAP was conducted in March, 1978, by USATHAMA. The purpose of this investigation was to identify and assess actual or potential chemical, biological, or radiological (CBR) contamination migration at MAAP. The review indicated that there was a potential for on-site contamination, as well as off-site migration, at potentially toxic concentrations. However, it was not determined if off-site migration was a function of current activities or past operation. It was recommended that a program be established to determine the extent of the migration hazard.

In 1979, USATHAMA initiated a two-phased program to characterize the state of environmental contamination at MAAP. The first phase, consisting of analysis of water samples from 11 private wells and 3 municipal wells outside MAAP boundaries, was completed in August 1979. It was concluded that there was no significant off-site contamination hazard from explosive waste in subsurface waters originating at MAAP (USATHAMA, 1982a). The second phase of the program involved an extensive environmental contamination survey of groundwater, surface streams, and ditches passing through MAAP, and known or suspected areas of surface contamination. The survey included installation of 33 shallow groundwater monitoring wells. The results suggested that off-site water supplies were not contaminated by explosive or organic contaminants originating at MAAP. However, groundwater and surface water within MAAP were contaminated with 2,4,6-TNT, 2,4-DNT, and RDX; and the contamination was shown to be moving slowly toward the plant boundaries. The results of the groundwater investigation also showed that the drinking water standard for mercury was exceeded at one location.

In addition, the survey found that lead and chromium exist in groundwater and surface water at MAAP. Migration in groundwater was inconclusive, and migration in surface streams and ditches was found to be slight. Other substances such as nitrate, nitrite, phosphate and sulfate anions exist in surface and/or subsurface waters within MAAP, but migration was not environmentally significant. Major sources of contaminant migration identified at MAAP included the wastewater lagoons at O-Line and the drainage ditches from this area. It was recommended that additional surface and subsurface testing be conducted to identify secondary sources of groundwater contamination at MAAP and to develop comprehensive

contamination abatement measures (USATHAMA, 1982). Also during this time, a program for cleanup of the O-Line Ponds had been initiated.

In 1983, Roy F. Weston, Inc. (Weston) performed an assessment of groundwater contamination at MAAP (USATHAMA, 1983a, 1983b, and 1983c). The report concluded that the principal source of groundwater contamination is the O-Line Ponds area, which has released contaminants to both the upper and middle depths of the Memphis Sand. Specific conclusions drawn by the authors of the report which pertain to the O-Line Ponds area are as follows:

- The principal source of explosives contamination to groundwater at MAAP are the O-Line Ponds. Groundwater samples from wells near the ponds contained higher concentrations (>1,000 μg/L) of RDX, TNT, and HMX and lesser amounts of TNB, DNB, and 2,4-DNT. Contaminants have migrated along a narrow front in a north-northwesterly direction.

- Nitrates and nitrites were found in groundwater throughout the site in concentrations well below 10 mg/L. Although some elevated levels (up to 16.8 mg/L for nitrates) were observed in wells near the O-Line Ponds, there is evidently a background level of nitrates and nitrites in the groundwater independent of sources from manufacturing. Any contamination from manufacturing activities is not generally distinguishable from background contamination, except very near the O-Line Ponds. Migration of nitrates and nitrites were determined not to be a matter of concern.

- Chromium was found in both deep and shallow wells downgradient from the O-Line Ponds. Highest concentrations (22-55 μg/L) were found in three deep wells, MI041, MI047 and MI053. However, no plume was identified. Only well MI041 exceeded the EPA drinking water standard for chromium of 50 μg/L. Lesser concentrations of chromium were also found in wells in the northwest boundary area.

A Groundwater Contamination Survey (USAEHA, 1988) was conducted in February 1988. The purpose of the survey was to identify and evaluate all SWMUs as part of a pending RCRA Part B permit application, and to delineate those units requiring further sampling, investigation and corrective action. At the time of the survey, investigation of two SWMUs (O-Line Ponds and OBG) were already in progress. It was recommended that as a precautionary measure, groundwater sampling of all existing monitoring and supply wells at MAAP be conducted for explosives contamination.

The facility has conducted regular sampling and analysis of groundwater from selected production and monitoring wells for the purpose of monitoring the extent of the contaminant plume. The wells in the vicinity of and downgradient from the O-Line Ponds area have been sampled annually since 1986. The analytical data from the O-Line Ponds area wells are available in the Installation Restoration Data Management System (IRDMS) database.

2.3.2.2 Summary of Remedial Investigation Results. The groundwater data collected during the RI show that an explosive-contaminated groundwater plume originates at the O-Line Ponds area and extends toward the northern boundary of the facility. Figures 2-12 through 2-23 present the concentrations of explosives and select metals (cadmium, chromium, mercury, and lead) detected in the wells downgradient and cross-gradient of the O-Line Ponds area during the RI field investigation. The concentration contour lines were drawn by interpolating between the data points, which are shown next to each well location. In the case of well clusters (sets of wells screened at different depths in the aquifer), the highest detected concentration was used in constructing the concentration contour lines.

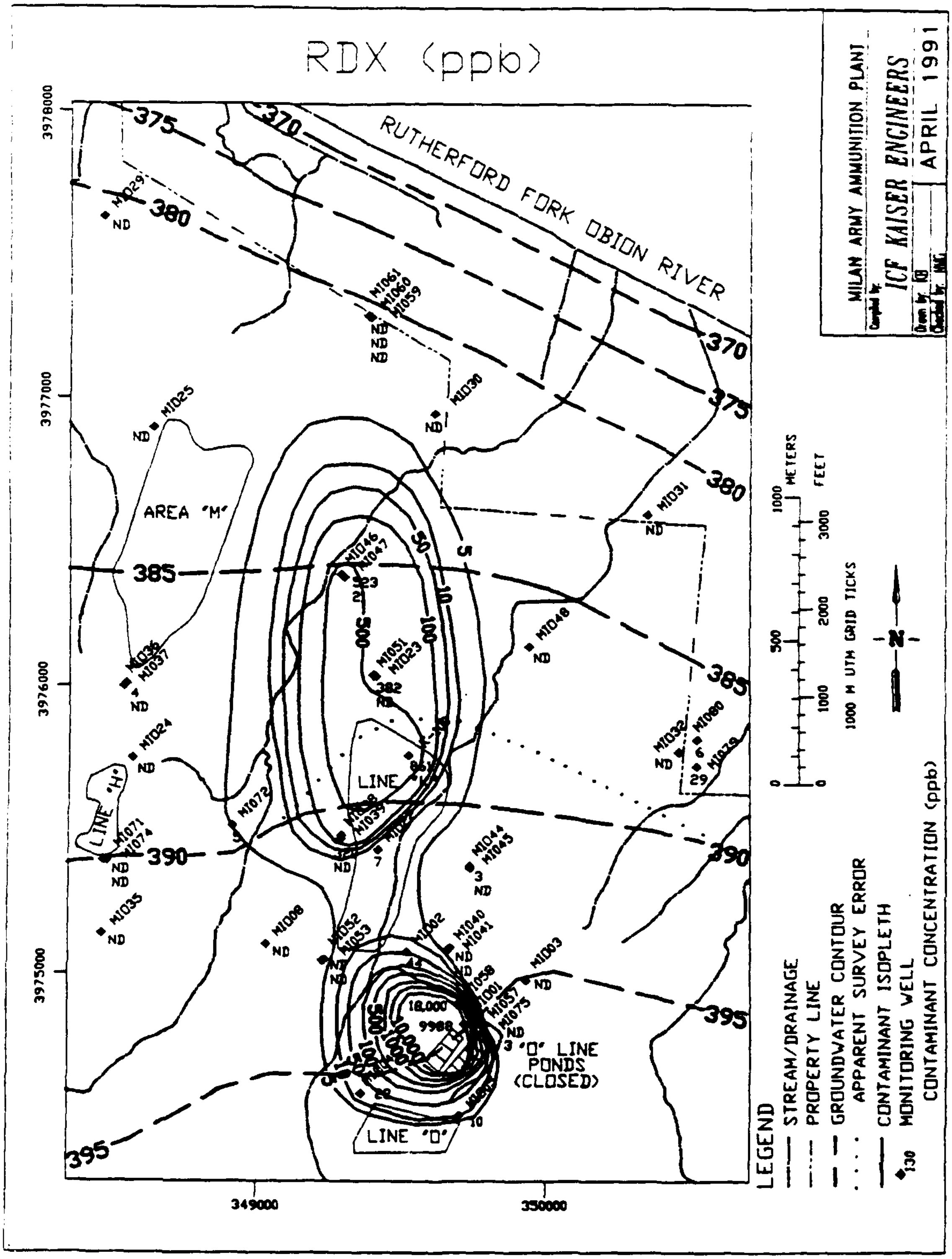

Figure 2-12

RDX Concentrations Associated With O-Line Ponds Area

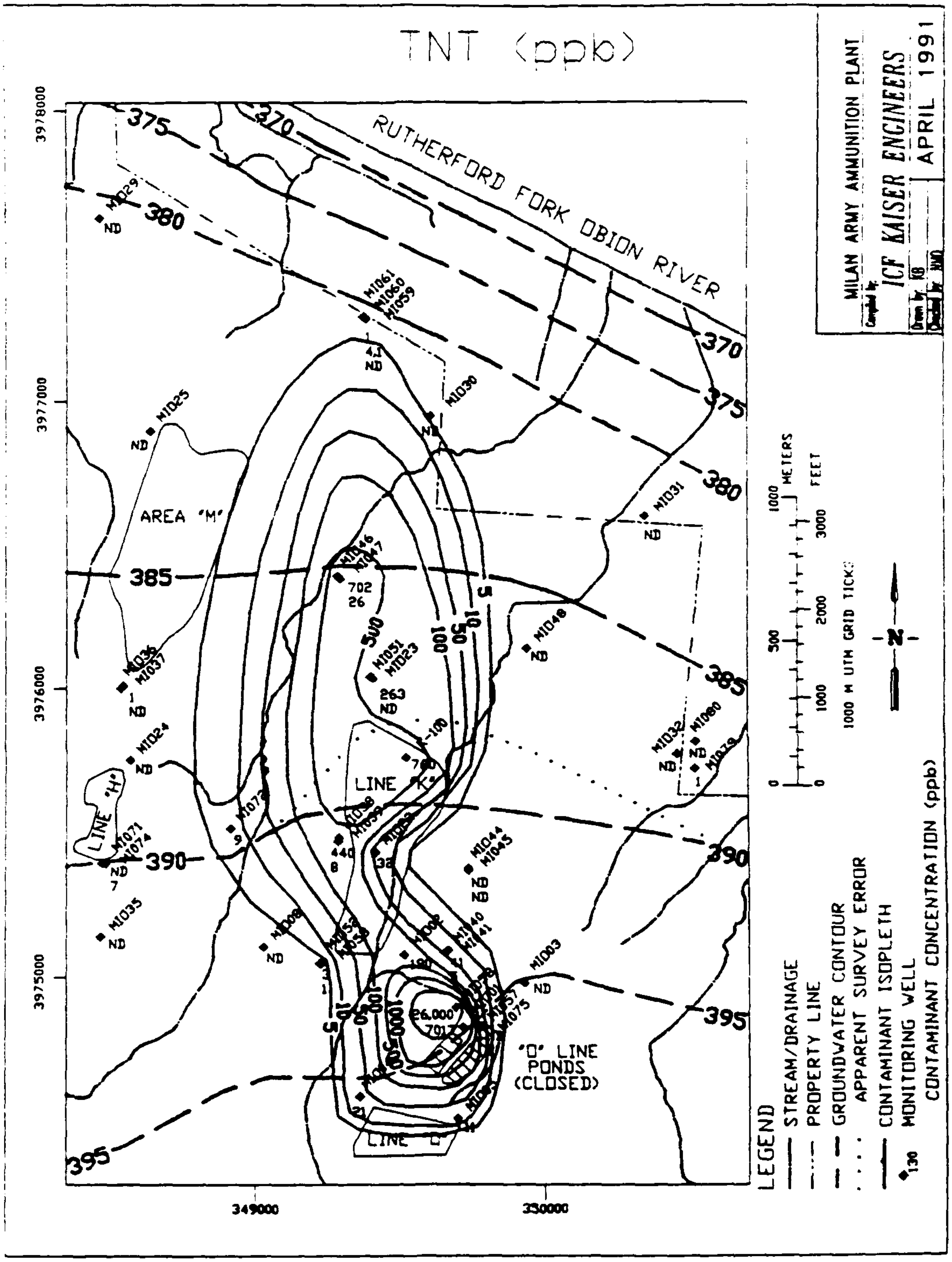

Figure 2-13

TNT Concentrations Associated With O-Line Ponds Area

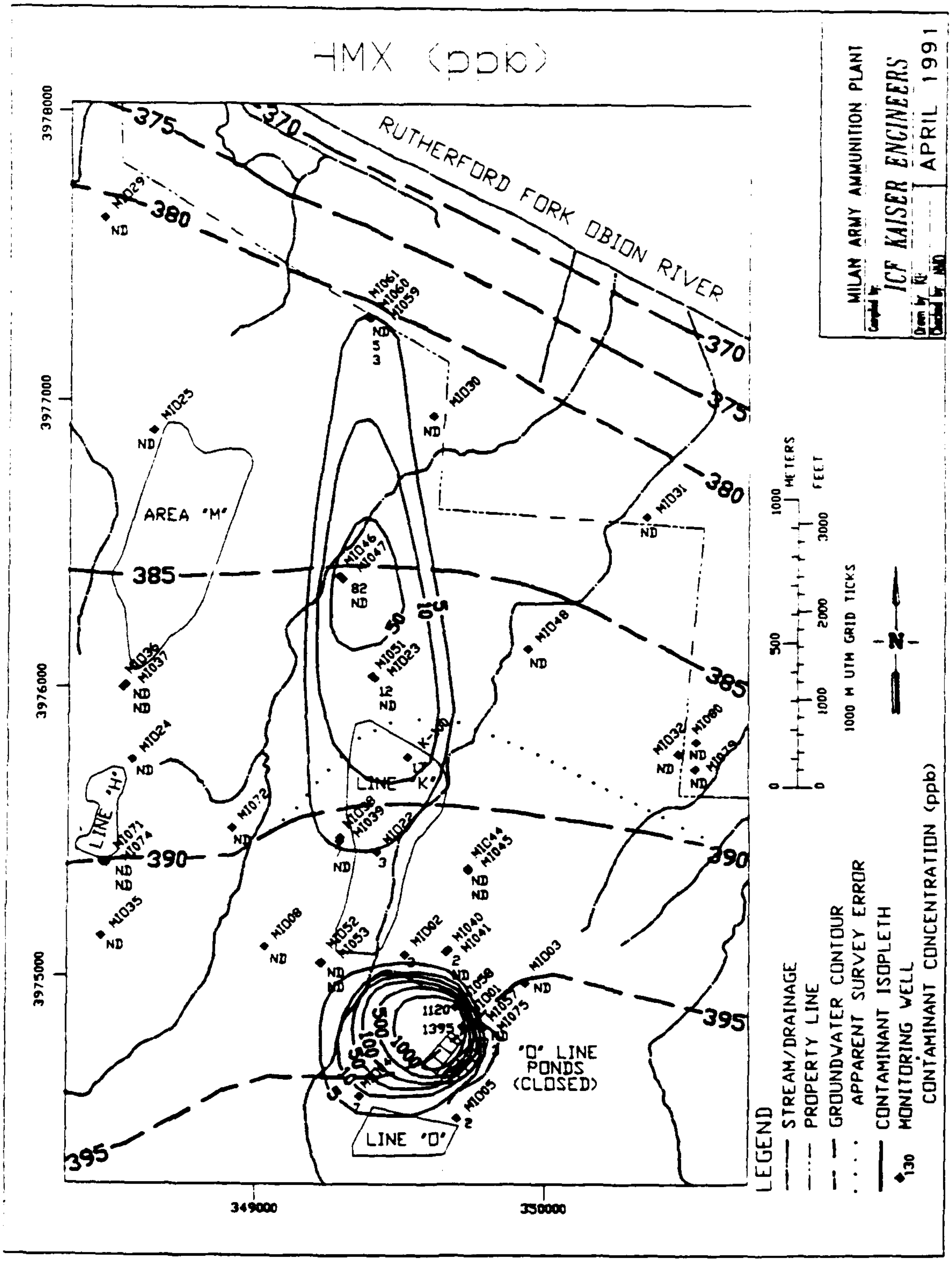

Figure 2-14
HMX Concentrations Associated With O-Line Ponds Area

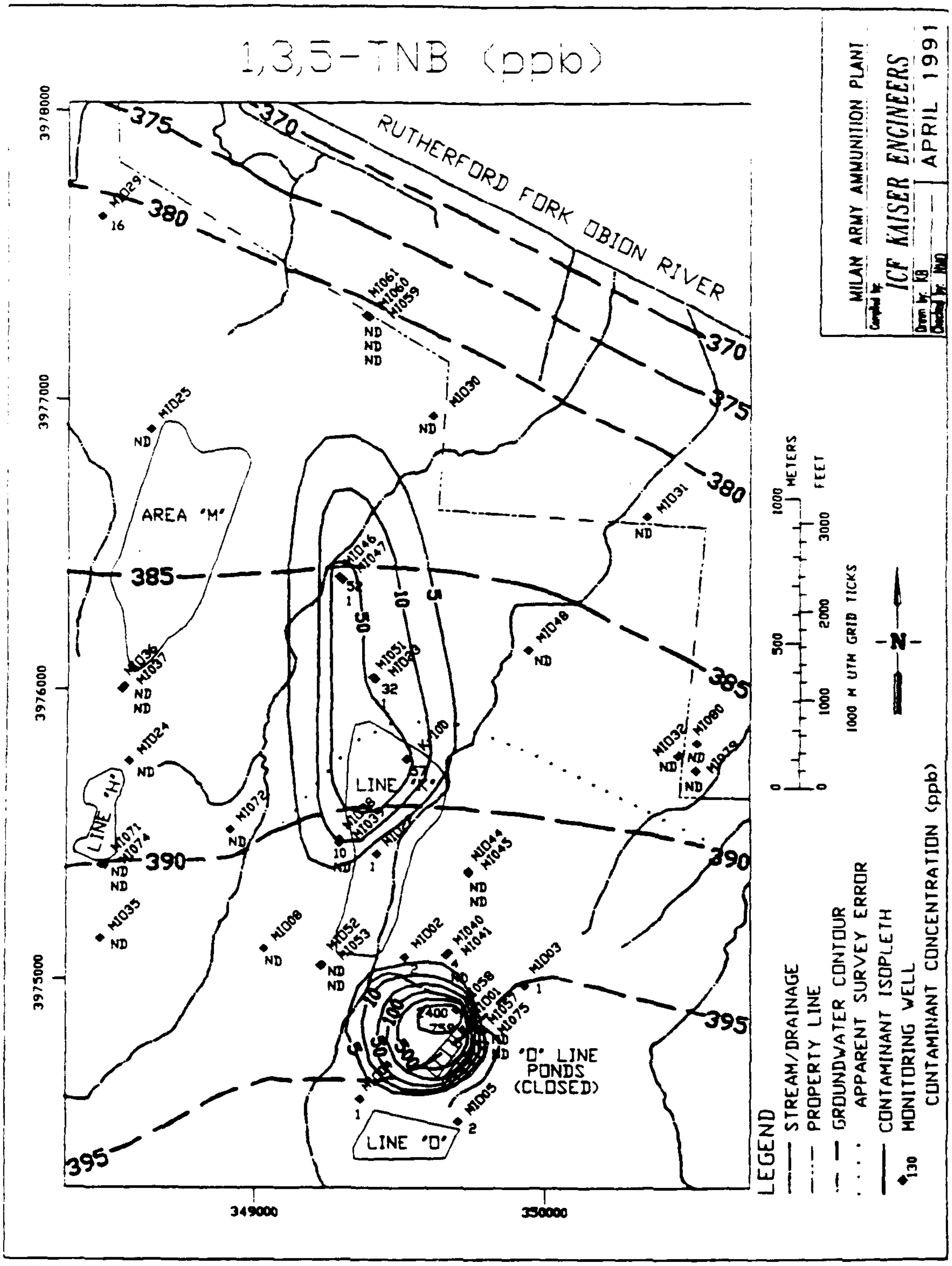

Figure 2-15
1,3,5-TNB Concentrations Associated With O-Line Ponds Area

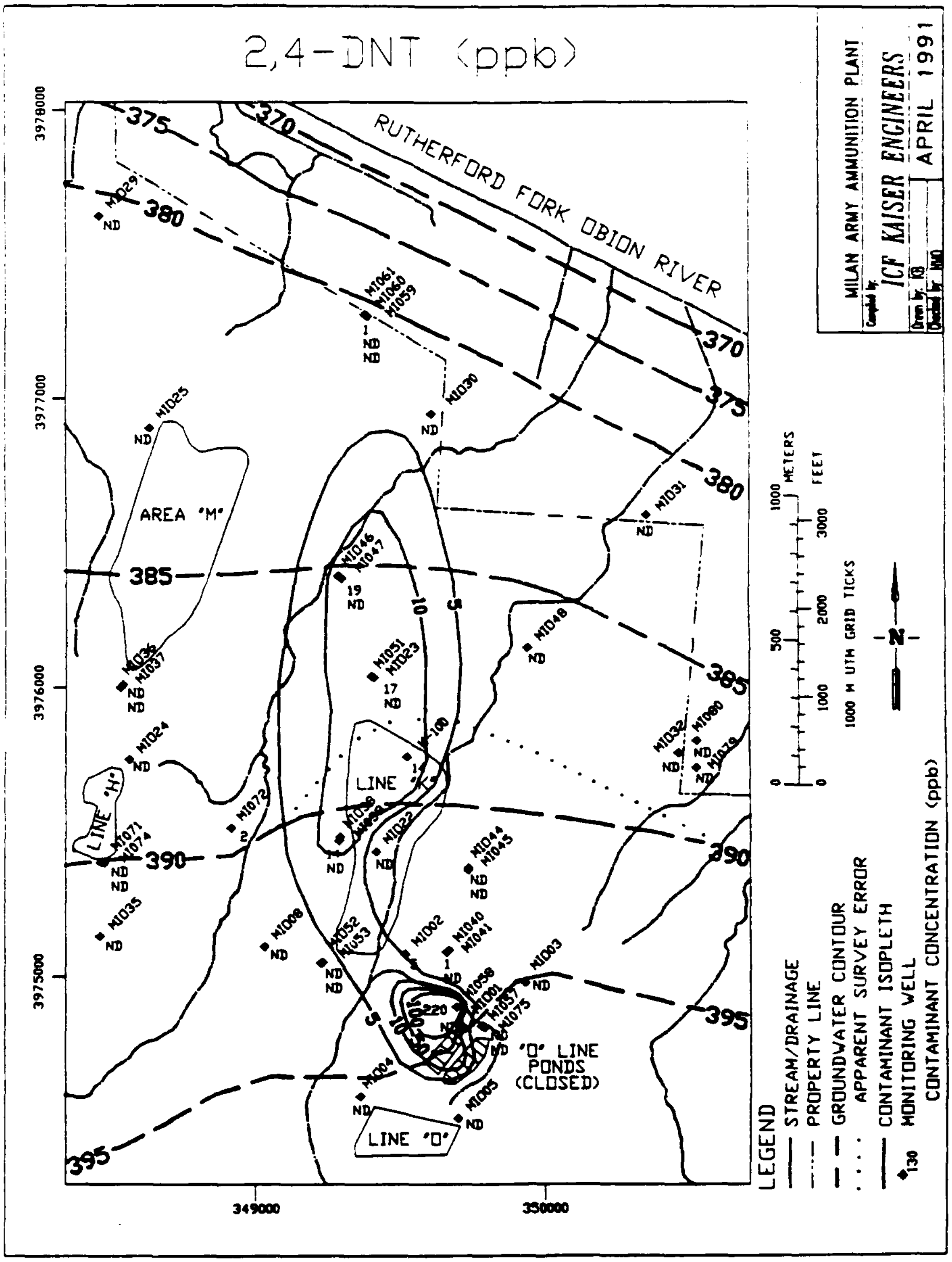

Figure 2-16

2,4-DNT Concentrations Associated With O-Line Ponds Area

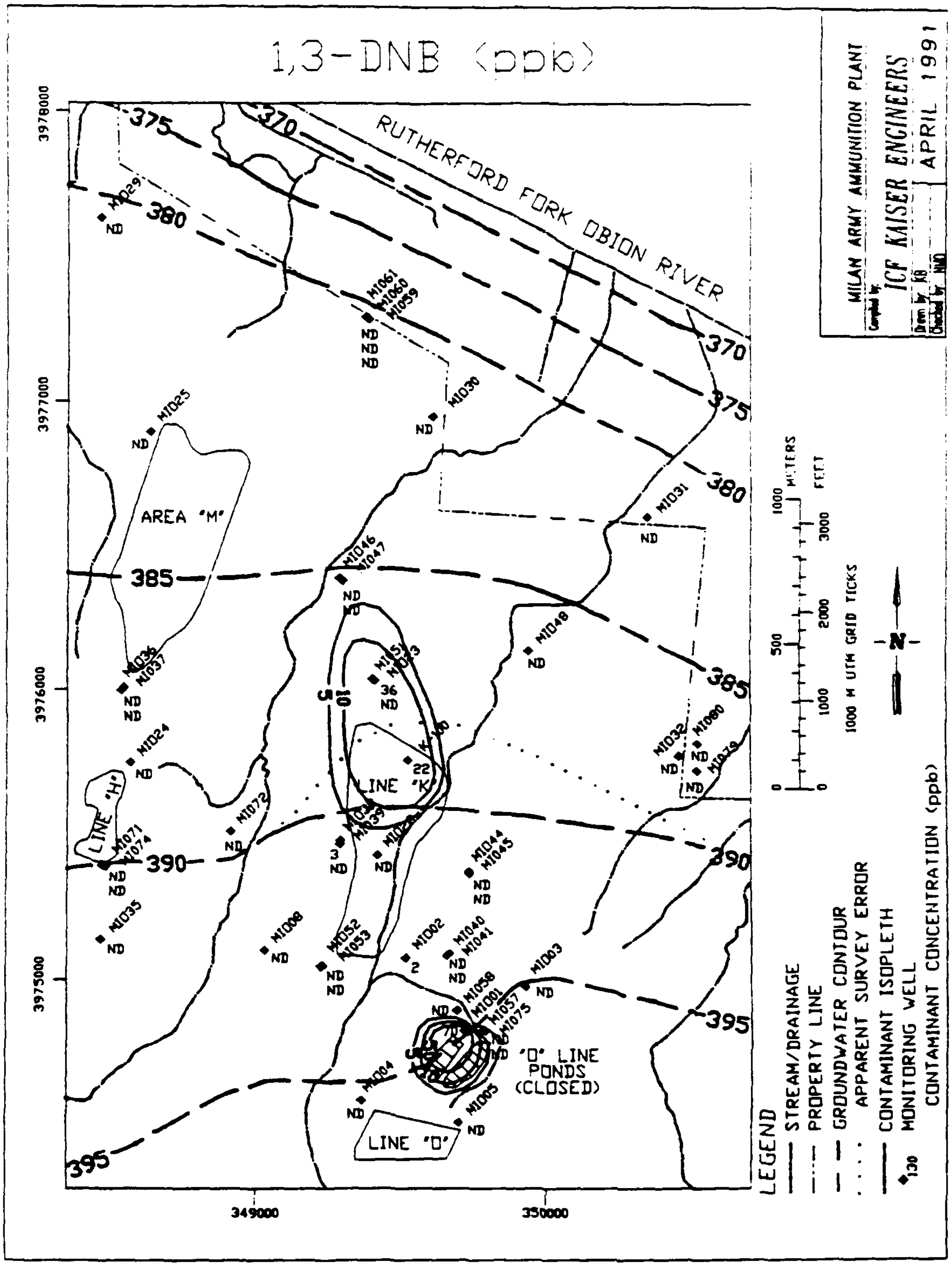

Figure 2-17
1,3-DNB Concentrations Associated With O-Line Ponds Area

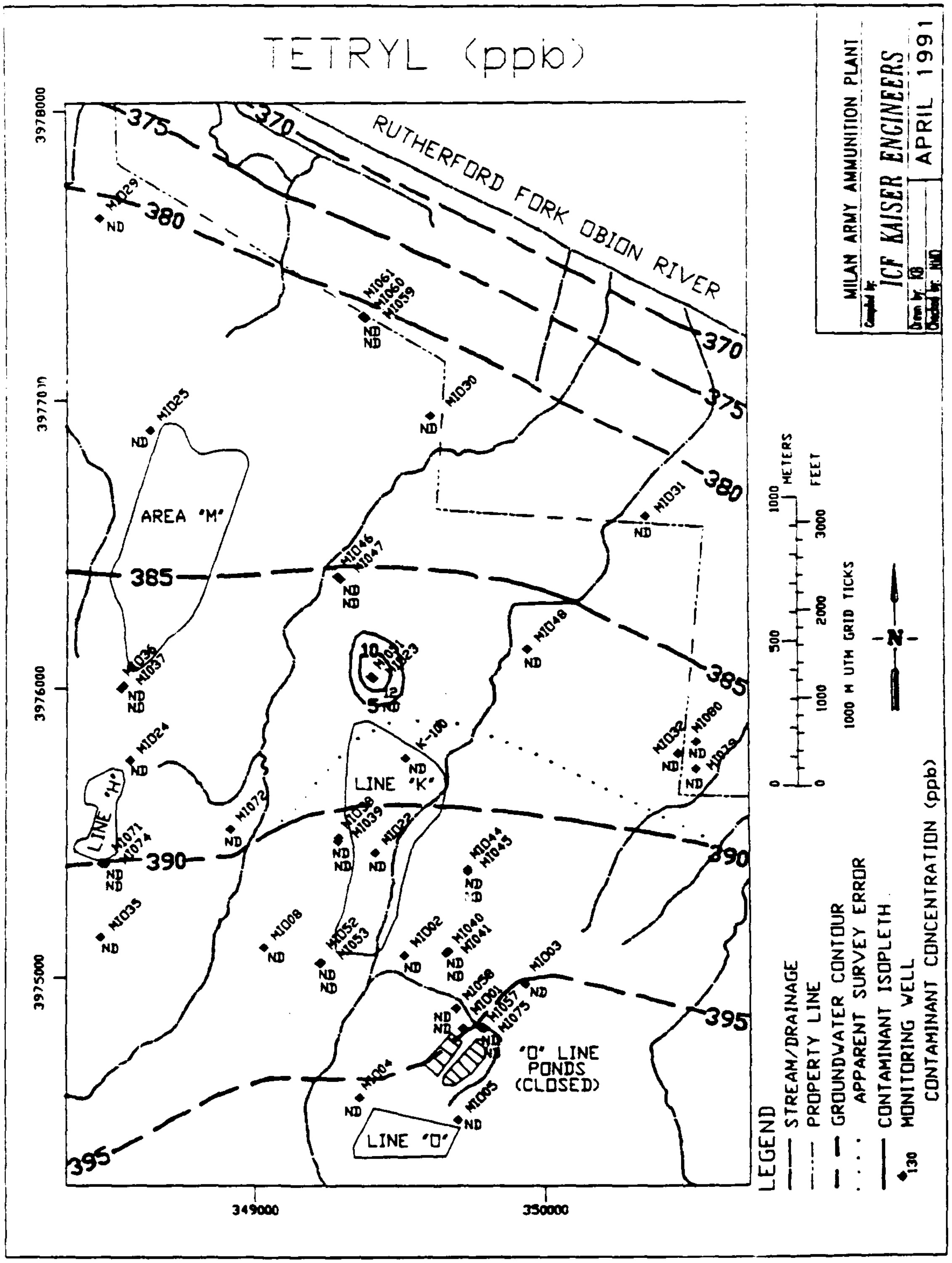

Figure 2-18
Tetryl Concentrations Associated With O-Line Ponds Area

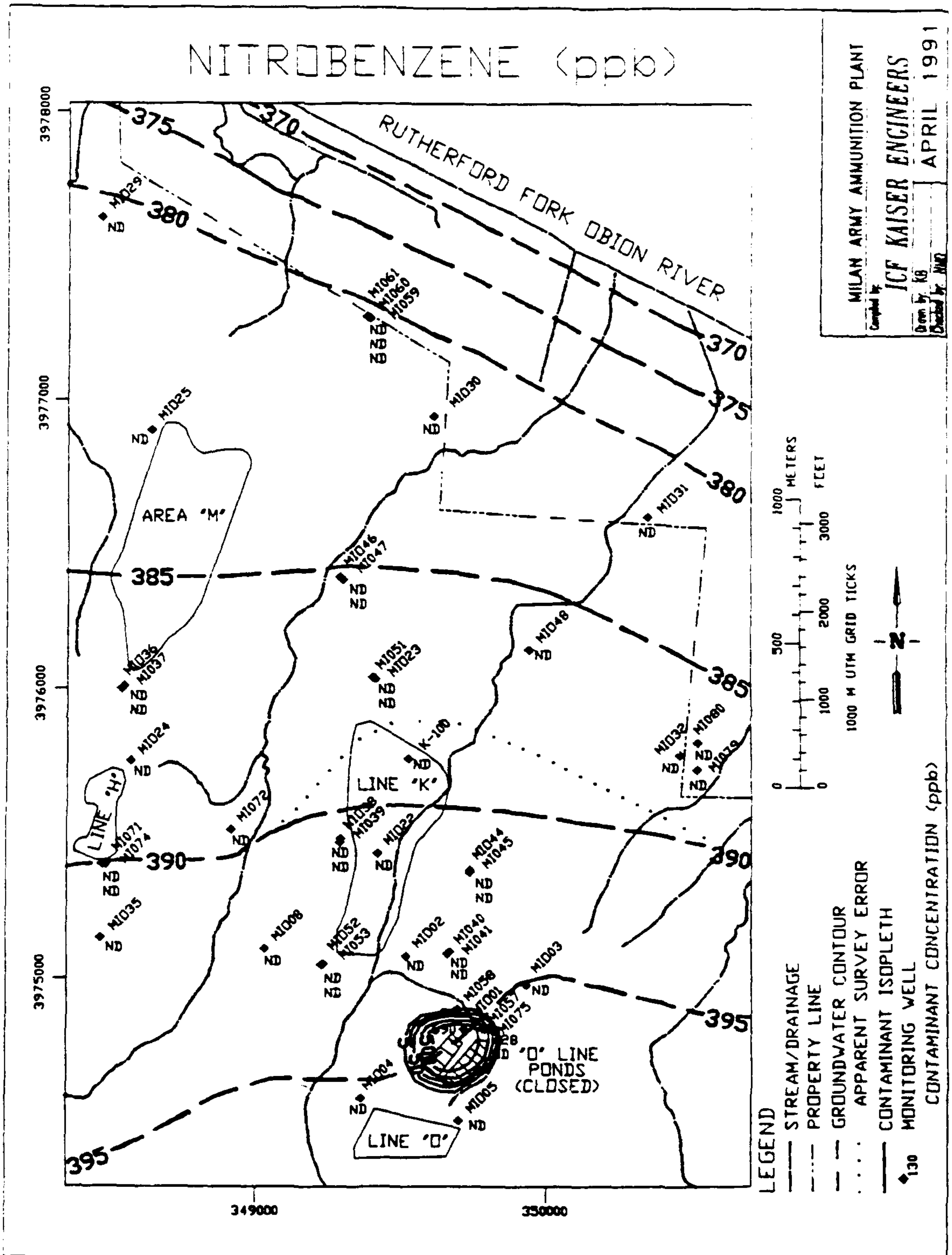

Figure 2-19
Nitrobenzene Concentrations Associated With O-Line Ponds Area

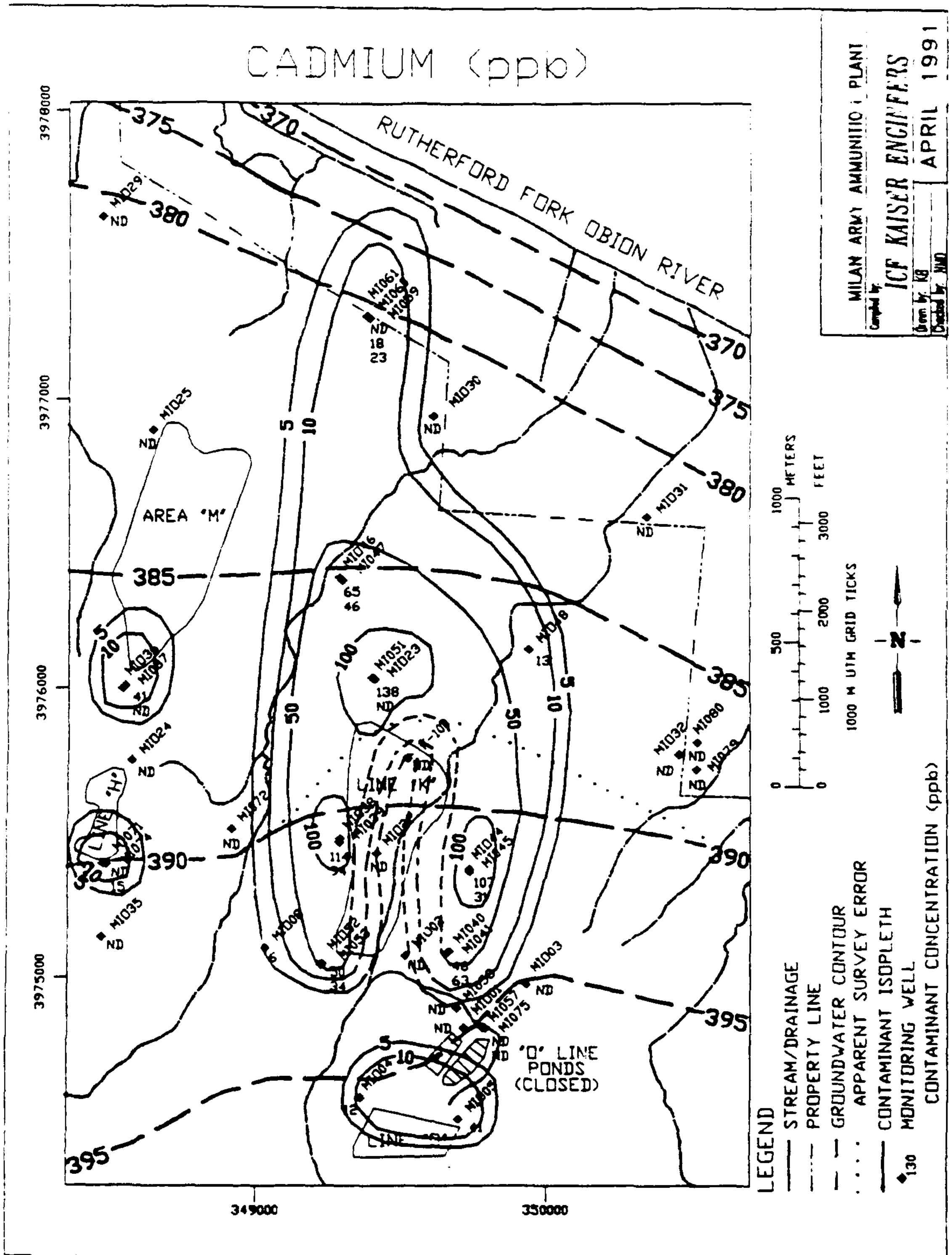

Figure 2-20
Cadmium Concentrations Associated With O-Line Ponds Area

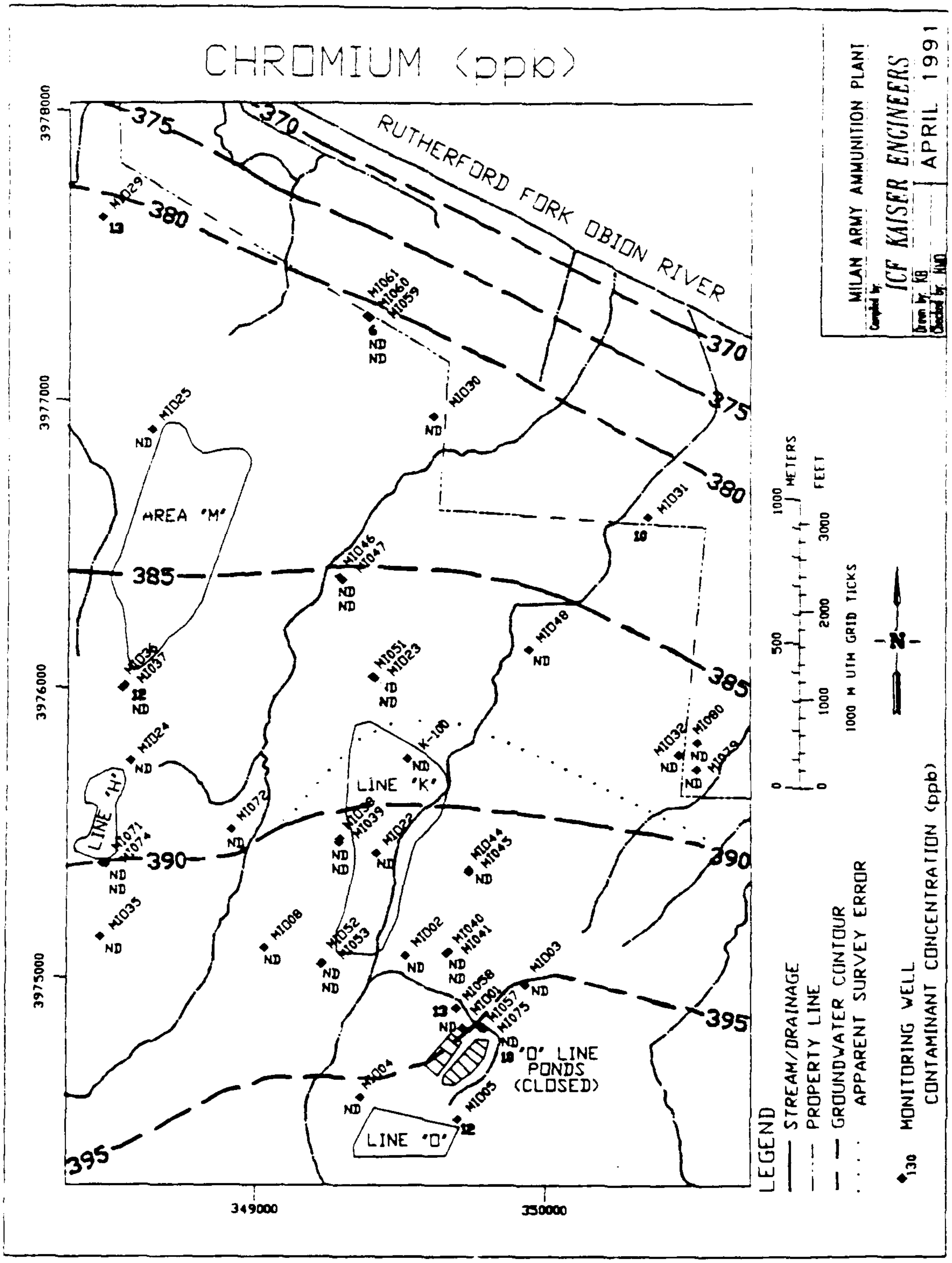

Figure 2-21

Chromium Concentrations Associated With O-Line Ponds Area

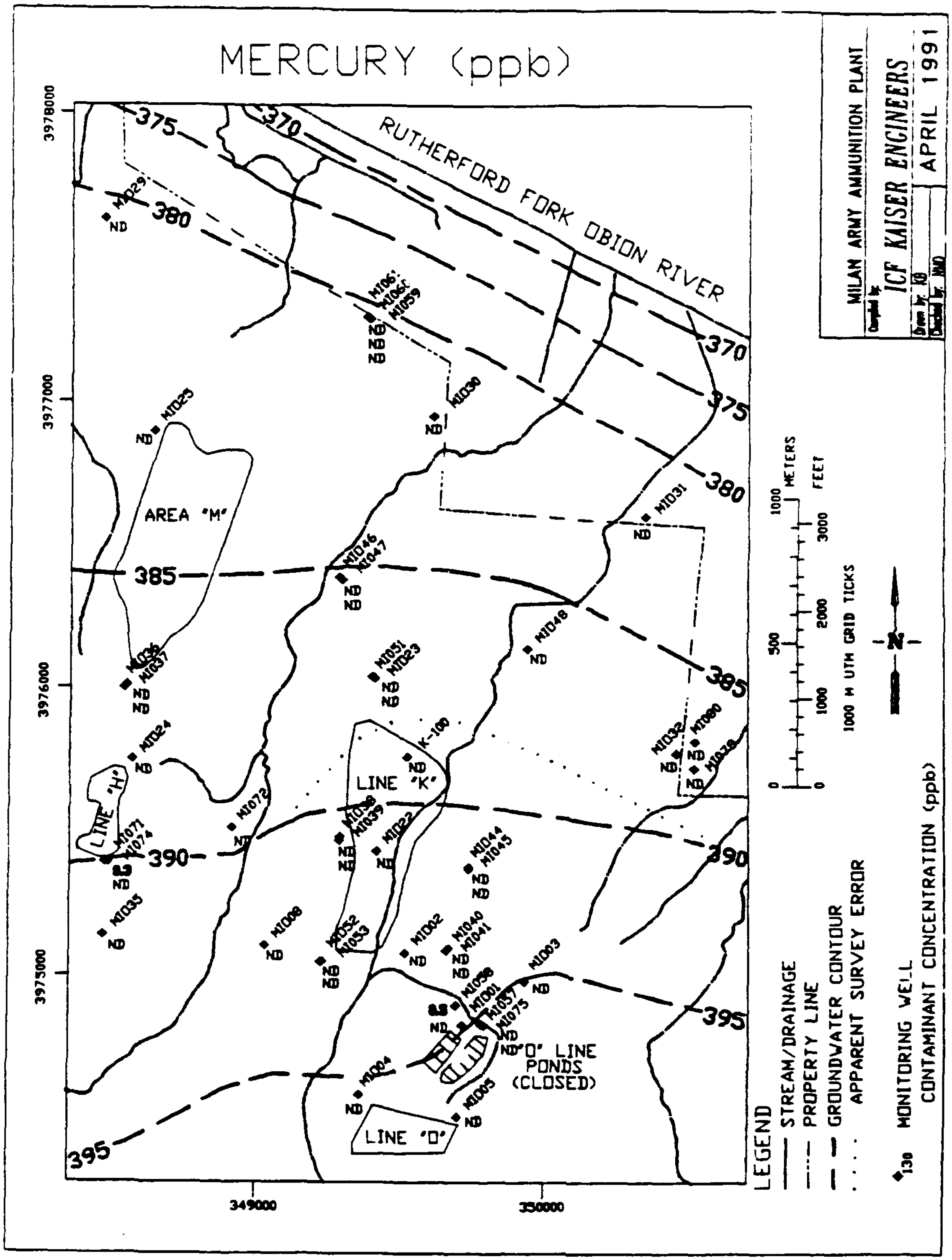

Figure 2-22
Mercury Concentrations Associated With O-Line Ponds Area

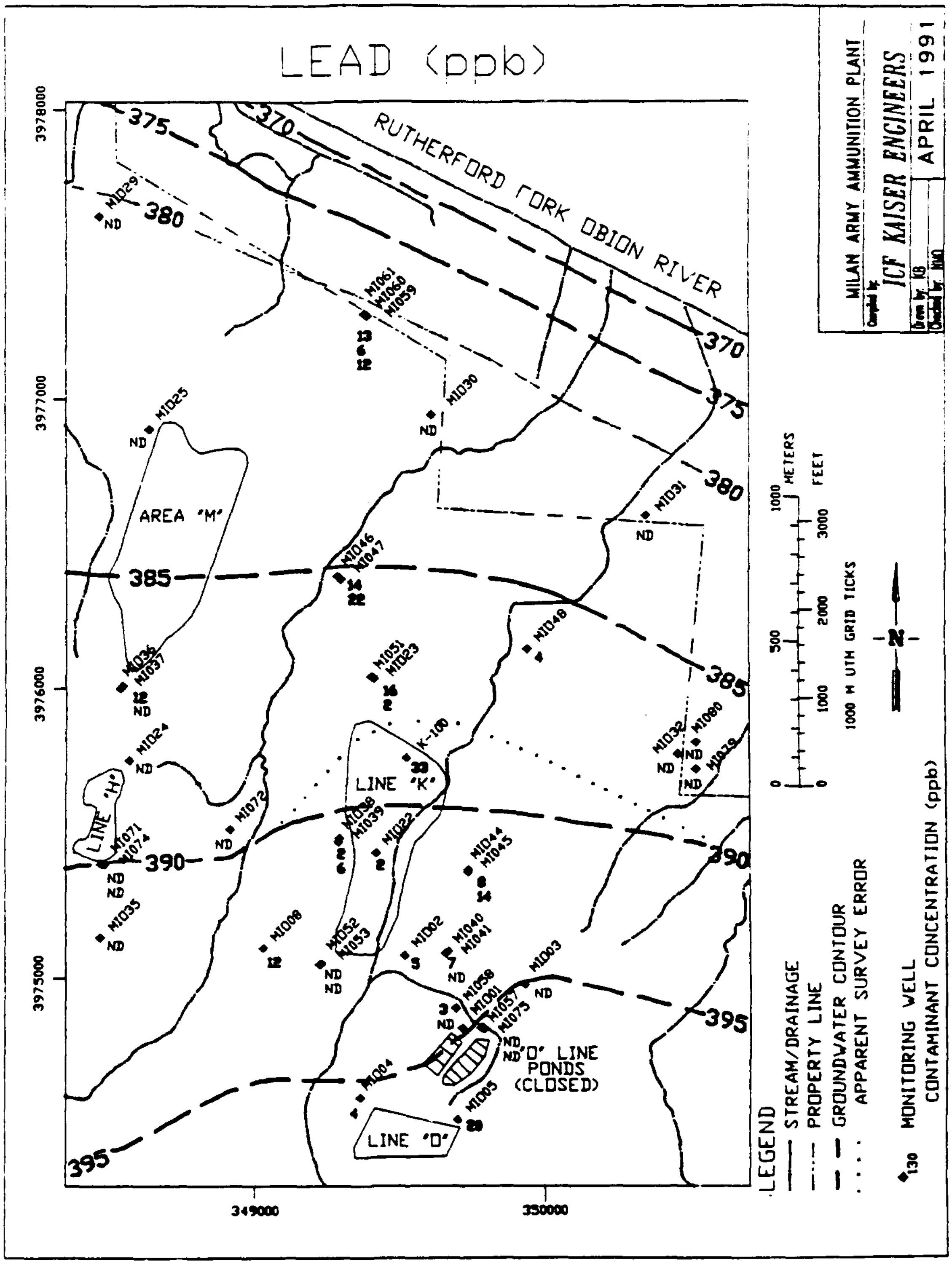

Figure 2-23

Lead Concentrations Associated With O-Line Ponds Area

The rate of contaminant transport through the groundwater is dictated predominantly by advection and dispersion processes. Advection is the transport of a non-reactive, conservative solute at an average groundwater velocity. Hydrodynamic dispersion is the combination of mechanical and chemical processes which cause the contaminant plume to spread out in the lateral, vertical, and transverse direction. Mechanical dispersion is the mixing that occurs as a solute is convected through a porous medium. Molecular diffusion is the other component of hydrodynamic dispersion, and it is driven by the concentration gradient of the solute. In situations where the scale of the problem is small (i.e., a laboratory column experiment) or the velocity of convective flow is very small, hydrodynamic dispersion is dominated by molecular diffusion. However, in most field situations, hydrodynamic dispersion is dominated by mechanical dispersion and molecular diffusion may be neglected.

The contaminants detected in well MI004 (south of the O-Line Ponds area) are probably due to longitudinal dispersivity, which has a greater relative effect in low groundwater flow rate systems.

Explosives. Figures 2-12 through 2-19 show that the explosive-contaminated plume emanating from the O-Line Ponds area appears to be moving toward the northern boundary. The plume, as it currently exists, encompasses a relatively narrow region between the ponds and the facility boundary. The southern limit is the area around the O-Line Ponds, which is the location of the highest concentrations. The plumes for TNT and HMX (Figures 2-13 and 2-14) extend to the northern boundary as these compounds were detected in cluster wells MI059, MI060, and MI061. The true northern extent of the plume for these two compounds cannot be determined using empirical evidence.

These figures indicate that Ditches B and C probably are concurrent sources of explosives contamination. For example, the RDX plume (Figure 2-12) contour lines around the O-Line Ponds show that the level of contamination is greatly attenuated as the distance from the ponds increases. The concentration of RDX then increases rapidly downgradient of Ditch B. The same trend is apparent in the plumes for the other detected explosive compounds.

It does not seem likely that Line K is the source of explosives in groundwater. According to facility personnel, explosives were not handled to a large extent at this line (personal communication, Tom Allen, Martin Marietta, February 27, 1991). There are no wastewate sumps at Line K.

Tetryl was detected once in the well cluster between Ditch B and Ditch C (Figure 2-18). Because this compound was not detected in the wells immediately downgradient of the O-Line Ponds, the ponds are apparently not the source. It is possible that the source of the detected tetryl is Ditch B.

The nitrobenzene plume is highly localized near the O-Line Ponds (Figure 2-19). Nitrobenzene is a contaminant of tetryl, is sometimes used as a solvent for TNT, and is a degradation product of TNT. As a breakdown product, it might be expected to appear in areas which are highly contaminated with TNT for a long period of time. It probably was not discharged to the ditches in significant quantities.

The plume from the O-Line Ponds and the plume from Ditch B appear to be distinct for several of the explosives (1,3-DNB, 1,3,5-TNB, and HMX). However, the source of both plumes is the O-Line operation. Wastewater was discharged to the ponds (where percolation to the water table occurred) and Ditch B received pond effluent and overflow concurrently. Therefore, the contaminants that comprise the two plumes are identical.

Further evidence that the ditches are or were sources of groundwater contamination is the extent of the explosives plume. If the ponds were the sole source of groundwater contamination, then Figures 2-13 and 2-14 show that 2,4,6-TNT and HMX have migrated at least 8,000 feet since groundwater contamination began. Using the calculated groundwater velocity of 0.2 ft/day, and assuming that the contaminants have been transported at the same rate as groundwater flow (this is a conservative

assumption because the transport of organic contaminants is retarded by sorption effects), then 110 years would be required to form the plume. Therefore, an intermediate source(s) of groundwater contamination must exist.

Select Metals. The groundwater results for select metals are presented in Figures 2-20 to 2-23. The only metal which appears to be emanating from a distinct source area is cadmium. Three monitoring wells near Line K were contaminated with high levels of cadmium. One of these wells, MI051, is located immediately downgradient from the former wastewater pond for the plating operation. The other two areas of high cadmium levels are on the east and west sides of Line K. The source of the contamination at these locations is not known. However, it appears from Figure 2-20 that the O-Line Ponds are not a significant source of cadmium.

The results for the other select metals (chromium, mercury, and lead), presented in Figures 2-21 to 2-23, do not indicate that a distinct source of these metals exists. The levels detected are not greatly elevated and there is no apparent pattern.

Other Organic and Inorganic Analytes. Approximately 20% of the 104 total groundwater samples were analyzed for TAL/TCL constituents and explosives. However, relatively few of these samples were collected from wells which are immediately downgradient of the O-Line Ponds. The following wells are downgradient of the O-Line Ponds and their respective samples were analyzed for TAL/TCL constituents:

- MI057 (top of screen at depth of 161 feet below ground surface, and immediately downgradient of O-Line);
- MI051 (top of screen at depth of 135 feet below ground surface, and approximately 4,300 feet NNW of the O-Line Ponds);
- MI030 (top of screen at depth of 31.5 feet below ground surface, and approximately 7,000 feet NNW of the O-Line Ponds); and
- MI060 (top of screen at depth of 141 feet below ground surface, and approximately 8,000 feet NNW of the O-Line Ponds).

The organic compounds detected in these wells are high molecular weight hydrocarbons such as tetracosane and hexacosane. These compounds were detected at the method detection limit in the samples from wells MI057 and MI030. The source of these compounds is not known, but the low concentrations and sporadic appearance in other groundwater samples indicates that laboratory contamination cannot be discounted. Other volatile organic compounds (VOCs), base/neutral/acid extractable compounds (BNAs), pesticides, and polychlorinated biphenyls (PCBs) were not detected in these samples.

Although MI057 is immediately downgradient of the O-Line Ponds, the fact that organic constituents were not detected in the groundwater sample does not necessarily indicate that organic contaminants are not migrating from the area in the shallow aquifer zone. The well is screened at a depth of 160 feet below ground surface and explosives, which were detected at high levels in the nearby shallow wells, were not detected in the samples from MI057. Based on the 1990 sampling of these wells, it appears that groundwater at this depth is relatively unaffected by contamination from O-Line.

Inorganic analytes (other than the select metals) were detected above their respective background levels in the wells downgradient of the O-Line Ponds. The concentrations of those analytes detected above background levels are presented in Table 2-6.

TABLE 2-6
Concentrations of Inorganic Analytes (μg/L) in Unfiltered Groundwater Samples; Downgradient of O-Line Ponds

Sample/Analyte	Al	Ba	Ca	Fe	K	Mn	Mg	Na	Zn
MI030+	333	42.2	8,090	450	NA	39.0	1,680	7,240	NA
MI051	NA	101	16,400	1,230	NA	56.7	4,110	5,070	239
MI057	NA	15.0	4,640	291	3,080	27.9	NA	NA	NA
MI060+	805	53.5	5,530	306	185,000	30.3	NA	29,300	NA

NA Not applicable; analyte not detected above background.

\+ Duplicate sample taken at this well; where the analyte was detected in both samples, the concentration is expressed as the average of the two samples.

2.3.2.3 Extent of Groundwater Contamination. The monitoring wells closest to the O-Line Ponds are MI001, MI058, MI057, and MI075. MI001 and MI058 are shallow wells, while MI057 and MI075 are screened at an intermediate depth in the aquifer. The contaminants detected in the shallow wells are TNT, RDX, 2,4-DNT, HMX, nitrobenzene, 1,3-DNB, 1,3,5-TNB, tetryl, and low levels of lead, mercury, and chromium.

The historical groundwater monitoring data for MI001 in the IRDMS database indicate that between 1986 and 1989, the levels of TNT, RDX, and TNB did not decrease significantly over time (Figure 2-24). These groundwater samples were collected by Martin Marietta employees and the samples were analyzed by the on-site chemical laboratory. The dotted line in this figure connects the Martin Marietta data to the data collected during the RI. The addition of these data indicate that although the level of 2,4,6-TNT detected in the groundwater at MI001 may have decreased slightly between 1989 and 1990, the levels of RDX and 1,3,5-TNB in groundwater remained relatively constant.

The chemical data collected during the RI indicate that the shallow groundwater under the ponds is being impacted by contamination emanating from the ponds. Groundwater samples collected from the shallow wells, MI001 and MI058, had very high levels of explosives. The intermediate wells, MI057 and MI075, had very low concentrations of explosives. Deep wells were not installed in this area. The relative concentrations of contaminants observed in the 1990 sampling of these four wells indicates that the levels of contaminants in groundwater may decrease with depth.

2.3.2.4 Summary of Post-RI Sampling and Analysis. In January and February 1992, additional field work was conducted by ICF under contract to USATHAMA to further evaluate the nature and extent of contamination at the O-Line Ponds area. Soil borings were completed to the water table to obtain samples for both physical and chemical analysis. Undisturbed samples were collected of the clay layer for hydraulic conductivity testing; the purpose of these data is to determine the effectiveness of the cap in preventing moisture loading onto the former pond sediments. In addition, groundwater samples were obtained from monitoring wells MI001, MI057, and MI058.

Preliminary (non-validated) data from chemical analyses of soil samples indicate that the levels of explosive compounds have decreased greatly beneath the cap. The implication of these data is that much of the residual contamination has drained through the vadose zone to the water table. The potential for further drainage and groundwater contamination will be estimated when final data are available.

Preliminary data from chemical analyses of groundwater samples indicate that the levels of explosive compounds in the shallow aquifer have not changed significantly from the time that the RI sampling occurred. The data further indicate that organic compounds with the exception of the explosives are not detectable in the groundwater immediately downgradient of the cap. Additional data was collected regarding the levels of both cations and anions; this preliminary information has been used in assessing treatment technologies for removal of inorganic constituents.

2.3.2.5 Summary of Existing Data for Surface Water and Sediment Samples. Surface water and sediment samples were collected from the drainage ditches, Wolf Creek, Johns Creek, Halls Branch, and the Rutherford Fork of the Obion River. In general, low levels of contaminants were detected in both surface water and sediment downstream of the NPDES outfalls and in the Open Burning Ground/Ammunition Destruction Areas. In all cases, the concentration of explosives in surface water is less than the NPDES permit limit of 1,000 μg/L total nitrobodies. Therefore, it cannot be determined if a source is contributing explosives to the surface water other than the permitted outfalls. A sediment sample collected from the drainage ditch immediately downgradient of O-Line had the highest detected concentration of explosives: 1 μg/g. In general, there was no evidence that contaminants have accumulated in the sediment.

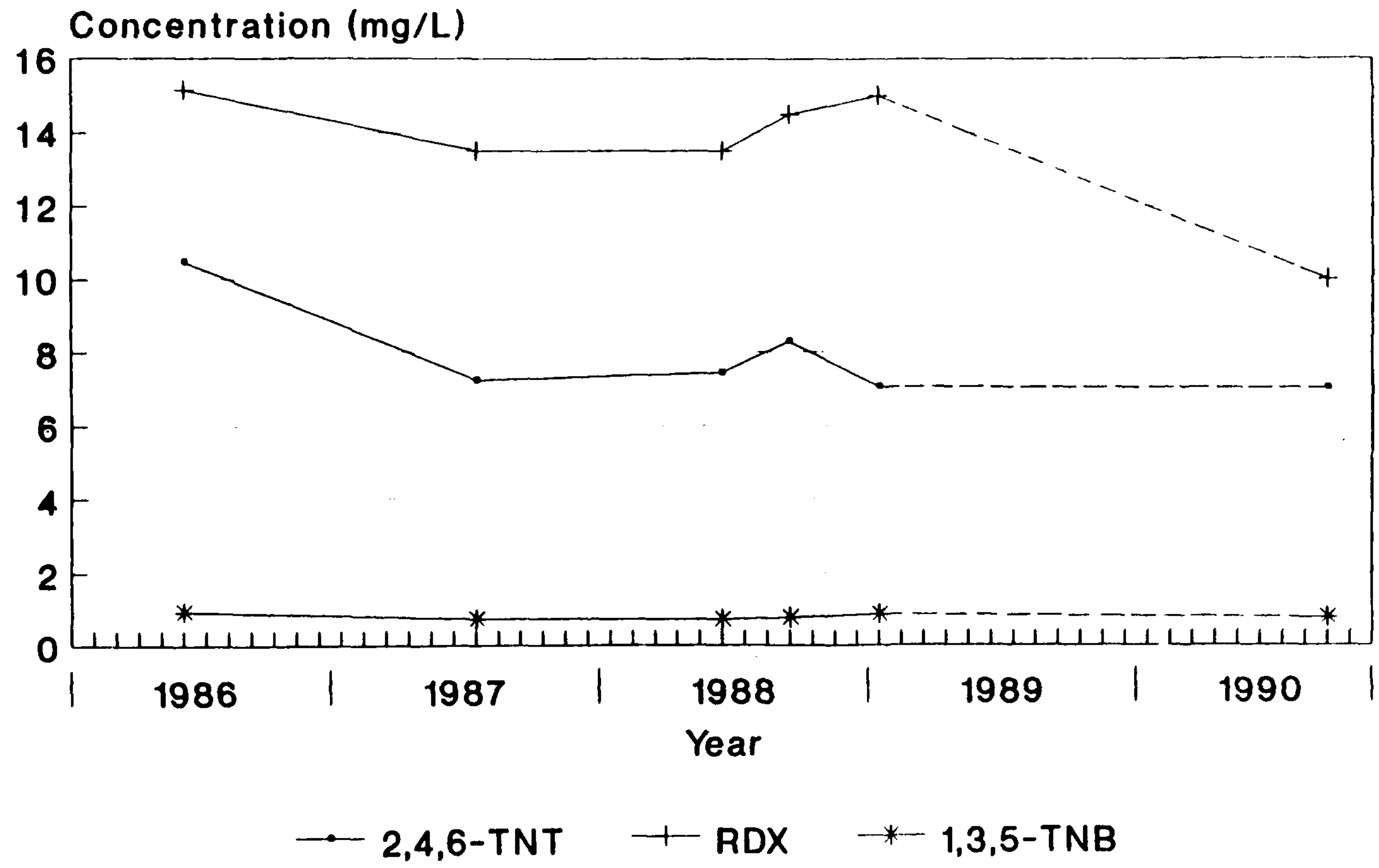

Figure 2-24

Concentration of TNT, RDX, and TNB Detected in MI001 Between 1986-1990

The characterization of the surface water hydrology patterns of the ditches indicates that the ditches lose water, which recharges groundwater. Based on this analysis, the contaminated groundwater emanating from the O-Line Ponds is not affecting surface water quality of the ditches. However, downgradient of the O-Line Ponds, near the Rutherford Fork of the Obion River, flow-net analysis of the aquifer indicates that shallow groundwater recharges surface water bodies in these areas. At the same time, the downward flow component which exists in the aquifer has the effect of pushing the contaminated groundwater deeper into the aquifer. An indication that this is happening are the cluster wells on the northern boundary of the facility. At this location, explosives were detected only in the intermediate well. If significant vertical flow is occurring, then it is less likely that the contaminated groundwater from the O-Line Ponds is or will discharge to the river at significant levels; instead, the plume may flow in a north-northwest direction toward regional discharge points.

2.3.3 Summary of Modeling Results

A two-dimensional contaminant transport computer model was used to calculate the movement of contaminated groundwater from the O-Line Ponds in the future. The model simulated the effects of advection, dispersion, and retardation for both organic and inorganic contaminants. The purpose of this modeling effort was to estimate the maximum lifetime exposure concentration for off-site drinking water use for the O-Line Ponds plume.

The assumption was made that although the drainage ditch near O-Line appears to be a concurrent source of groundwater contamination, the long-term significant source of contamination is the O-Line Ponds. Therefore, the existing groundwater contaminant plumes were matched by running the model using the O-Line Ponds as the source. The model was then run into the future for the length of time needed in order for the contamination profile at the northern boundary of the site to reach quasi-steady state; that is, the concentrations at the site boundary changed very little for an additional 50 years. This contaminant distribution represents the maximum potential concentration of explosives at the northern boundary of the facility. The contaminant profile was then averaged across the entire extent of the northern boundary to obtain an average value for the contaminant concentration. This average value was used as the exposure concentration for off-site residents in the risk assessment.

The computer model was used to calculate the transport of the explosive compounds and cadmium. For the other organic and inorganic contaminants, insufficient data were available to perform the modeling. For these cases, the exposure concentration was determined in a more conservative way, as described in the summary of risk assessment results.

2.4 SUMMARY OF RI RISK ASSESSMENT RESULTS

The significant findings of the risk assessment performed as part of the RI are summarized in this section. Although a variety of exposure pathways were qualitatively or quantitatively investigated, only those pathways associated with the O-Line Ponds will be discussed.

It should be noted that a key assumption of the RI risk assessment presented in this section is the use of institutional controls. It is assumed in this section that MAAP will not be developed for residential use (without prior remediation of contaminated groundwater) and therefore only off-site residents could be exposed to contaminated groundwater. This assumption represents the most likely future conditions at MAAP, but may not represent the reasonable maximum exposure scenario, which is required by the NCP.

To address this issue, a second risk assessment was performed for the O-Line Ponds groundwater. This risk assessment is referred to throughout this document as the baseline risk assessment, and it is presented in Section 2.5. For the baseline risk assessment, institutional controls

were not assumed. The exposure scenario for the baseline risk assessment is future residential use at the O-Line Ponds area itself and ingestion of contaminated groundwater.

The remainder of Section 2.4 discusses the results of the RI risk assessment.

2.4.1 Chemicals of Potential Concern

In this assessment, a set of chemicals of potential concern was selected for detailed evaluation based on the RI sampling results. Using a conservative selection procedure, chemicals were selected for four media (groundwater, surface soil, surface water, and sediment). A variety of organic and inorganic chemicals have been detected at MAAP, in addition to the explosive compounds and the four metals that were the focus of the field investigation. The explosive chemicals and several organic chemicals that are solvents most likely associated with manufacturing and production at the LAP lines were detected in each medium. Many inorganic chemicals also were detected in each medium. Because so few background samples were collected in each of the sampled media, background levels of chemicals of concern have not been well characterized. Nevertheless, many of the inorganic chemicals detected at low concentrations were retained as chemicals of concern, although they could be well within background levels.

The non-explosive organic compounds which are listed as chemicals of potential concern, chloroform and bis(2-ethylhexyl) phthalate, were detected in well MI006, which is upgradient of the O-Line Ponds (approximately 2,400 feet south of O-Line). These chemicals were retained in the risk assessment because the groundwater flow pattern indicates that contaminants at this location will eventually join the O-Line Ponds plume and continue north to the facility boundary. Although these contaminants were not detected downgradient of the O-Line Ponds, they were detected in the pond water before the cap was constructed (USATHAMA, 1982a) and therefore the potential for groundwater contamination exists.

2.4.2 Exposure Assessment

To evaluate the potential human health risks associated with the O-Line Ponds, several exposure pathways were selected for detailed evaluation. The exposure pathways that were quantitatively and qualitatively evaluated were:

- Residential drinking water exposures of future groundwater users at the northern boundary of MAAP (quantitative); and
- Residential inhalation and dermal exposures during in-home use of groundwater (qualitative).

Due to institutional controls at MAAP, drinking water ingestion exposures for potable water were not evaluated for those who work and live there. Several wells at MAAP are used for non-potable water, and dermal exposures and exposures from inhalation of chemicals that have volatilized during use could occur. These exposures are not expected to be significant, as few volatile chemicals were detected in groundwater, and those that were, were detected at low concentrations.

Exposure scenarios for each of the potential exposure pathways that was quantitatively evaluated were developed, and exposure point concentrations and chronic daily intakes (CDIs) of exposed populations were made. In this assessment, the reasonable maximum exposure (RME) case was evaluated in accordance with EPA guidance on conducting risk assessments at Superfund sites. For the groundwater exposure pathway, it was assumed that chemical concentrations in the environmental media sampled (or modeled) would remain constant over the duration of the exposure period assumed. In the absence of any site-specific information to the contrary, other exposure parameters used to estimate

potential intakes for potentially exposed populations were based on EPA standard assumptions and/or professional judgement.

The exposure point concentrations and chronic daily intakes are presented in Table 2-7. The concentrations for the explosives and cadmium are the result of the contaminant transport modeling described above. For the other contaminants, the exposure point concentration is the lower value of the 95% upper confidence level on the population mean concentration and the maximum detected value.

2.4.3 Risk Characterization

Quantitative risk assessment involves combining intakes for exposed populations with reference doses (RfDs, defined as acceptable daily doses for noncarcinogens) or slope factors (for carcinogens) to derive estimates of noncarcinogenic hazard, or excess lifetime cancer risks, of the potentially exposed populations. For carcinogens, potential risks are presented as the product of the CDI and slope factors. Risks were compared to EPA's target risk range of 10^{-4} to 10^{-6}. For noncarcinogens, potential hazards are presented as the ratio of the CDI to the reference dose (CDI:RfD), and the sum of the ratios is referred to as the hazard index. In general, hazard indices that are less than one are not likely to be associated with adverse health effects, and are therefore less likely to be of regulatory concern than hazard indices greater than one.

The potential risks associated with ingestion of groundwater by future residents at the northern boundary of MAAP are presented in Table 2-8. For the receptor populations at the northern boundary of MAAP, risks exceed the 10^{-6} risk level, primarily due to arsenic, RDX, and 2,4,6-TNT. However, it is important to note that RDX and 2,4,6-TNT are Class C carcinogens. The carcinogenic risks from such possible human carcinogens are based on inadequate evidence from human studies and adequate evidence from animal studies. Therefore, the carcinogenic risk levels are calculated conservatively and could be over-estimated. In addition, arsenic was present in low concentrations and may well be within background levels, and so risks due to arsenic also could be over-estimated. The total hazard indices for groundwater ingestion exceed 1, primarily due to manganese, 1,3,5-TNB, 2,4,6-TNT, and vanadium.

Potential residents in the future could be exposed to organic chemicals of concern via inhalation of chemicals that have volatilized during use, and via dermal absorption. Inhalation and dermal exposures to chemicals in groundwater are not expected to be significant, relative to those associated with ingestion exposures.

2.4.4 Ecological Impacts

Potential ecological impacts associated with the chemicals of potential concern at the MAAP site were evaluated. Potential impacts on plants, terrestrial wildlife, and aquatic life were evaluated either qualitatively or quantitatively, depending upon the availability of exposure and toxicity information and the likelihood of significant exposure. It should be noted that this ecological assessment is a facility-wide generalization, and may not be directly applicable to the O-Line Ponds area.

The conclusions of the environmental assessment are as follows:

Terrestrial wildlife. Potential impacts were evaluated for wildlife exposed to chemicals of potential concern in soil, surface water and food. Impacts to deer, the indicator species for terrestrial wildlife, from ingestion of surface water are not predicted based on the available toxicity data. Exposure of terrestrial wildlife and livestock to chemicals in food also are not expected to result in significant impact due to the localized nature of the contamination at MAAP relative to the available foraging habitat.

Table 2-7

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR
INGESTION OF GROUNDWATER BY FUTURE RESIDENTS AT THE NORTHERN BOUNDARY OF MAAP (a)

Chemicals Exhibiting Carcinogenic Effects (b)	Exposure Point Concentration (ug/L)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)
Organic Chemicals:		
Chloroform (CHCL3)	0.4	6.5E-06
2,4-DNT (24DNT)	0.14	2.3E-06
bis(2-Ethylhexyl)phthalate (B2EHP)	5.6	9.1E-05
RDX (RDX)	28.2	4.6E-04
2,4,6-TNT (246TNT)	29	4.7E-04
Inorganic Chemicals:		
Arsenic (AS)	1.9	3.1E-05

Chemicals Exhibiting Noncarcinogenic Effects (b)	Exposure Point Concentration (ug/L)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)
Organic Chemicals:		
Chloroform (CHCL3)	0.4	1.5E-05
1,3-DNB (13DNB)	0.2	7.6E-06
bis(2-Ethylhexyl)phthalate (B2EHP)	5.6	2.1E-04
HMX (HMX)	3.4	1.3E-04
Nitrobenzene (NB)	0.72	2.7E-05
RDX (RDX)	28.2	1.1E-03
1,3,5-TNB (135TNB)	4.6	1.7E-04
2,4,6-TNT (246TNT)	29	1.1E-03
Inorganic Chemicals:		
Arsenic (AS)	1.9	7.2E-05
Barium (BA)	371	1.4E-02
Cadmium (CD)	1.4	5.3E-05
Chromium (CR)	5.4	2.0E-04
Manganese (MN)	16,000	6.1E-01
Mercury (HG)	0.1	3.8E-06
Silver (AG)	13	4.9E-04
Vanadium (V)	24.9	9.5E-04
Zinc (ZN)	239	9.1E-03

(a) CDIs are calculated only for chemicals of potential concern with oral toxicity criteria. The following chemicals are not presented due to lack of oral toxicity criteria: aluminum, calcium, iron, magnesium, potassium, sodium and tetryl.
(b) USATHAMA chemical codes are listed in parentheses.

Table 2-8

POTENTIAL RISKS ASSOCIATED WITH INGESTION OF GROUNDWATER
BY FUTURE RESIDENTS AT THE NORTHERN BOUNDARY OF MAAP (a)

Chemicals Exhibiting Carcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Cancer Slope Factor (mg/kg-day)-1	Weight of Evidence Class (c)	Upper Bound Excess Lifetime Cancer Risk
Organic Chemicals:				
Chloroform (CHCL3)	6.5E-06	6.1E-03	B2	4E-08
2,4-DNT (24DNT)	2.3E-06	6.8E-01	B2	2E-06
bis(2-Ethylhexyl)phthalate (B2EHP)	9.1E-05	1.4E-02	B2	1E-06
RDX (RDX)	4.6E-04	1.1E-01	C	5E-05
2,4,6-TNT (246TNT)	4.7E-04	3.0E-02	C	1E-05
Inorganic Chemicals:				
Arsenic (AS)	3.1E-05	2.0E+00	A	6E-05
Total	--	--	--	1E-04

Chemicals Exhibiting Noncarcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Reference Dose (RfD) (mg/kg-day)	Uncertainty Factor (d)	Target Organ (e)	CDI:RfD Ratio
Organic Chemicals:					
Chloroform (CHCL3)	1.5E-05	1.0E-02	1,000	Liver	2E-03
1,3-DNB (13DNB)	7.6E-06	1.0E-04	3,000	Spleen/Weight	8E-02
bis(2-Ethylhexyl)phthalate (B2EHP)	2.1E-04	2.0E-02	1,000	Liver	1E-02
HMX (HMX)	1.3E-04	5.0E-02	1,000	Liver	3E-03
Nitrobenzene (NB)	2.7E-05	5.0E-04	10,000	Liver/Kidney	5E-02
RDX (RDX)	1.1E-03	3.0E-03	100	Prostate	4E-01
1,3,5-TNB (135TNB)	1.7E-04	5.0E-05	10,000	Spleen	3E+00
2,4,6-TNT (246TNT)	1.1E-03	5.0E-04	1,000	Liver	2E+00
Inorganic Chemicals:					
Arsenic (AS)	7.2E-05	1.0E-03	1	Skin	7E-02
Barium (BA)	1.4E-02	7.0E-02	3	Cardiovasc. system	2E-01
Cadmium (CD)	5.3E-05	5.0E-04 (f)	10	Kidney	1E-01
Chromium (CR)	2.0E-04	5.0E-03 (g)	500	CNS	4E-02
Manganese (MN)	6.1E-01	1.0E-01	1	CNS	6E+00
Mercury (HG)	3.8E-06	3.0E-04	1,000	Kidney	1E-02
Silver (AG)	4.9E-04	3.0E-03	2	Skin (Argyria)	2E-01
Vanadium (V)	9.5E-04	7.0E-03	100	None observed	1E-01
Zinc (ZN)	9.1E-03	2.0E-01	10	Anemia	5E-02
Hazard Index (h)	--	--	--	--	>1 (1E+01)

(a) Risks are calculated only for chemicals of potential concern with oral toxicity criteria. The following chemicals are not presented due to lack of oral toxicity criteria: aluminum, calcium, iron, magnesium, potassium, sodium and tetryl.
(b) USATHAMA chemical codes are listed in parentheses.
(c) EPA Weight of Evidence for Carcinogenic Effects:
[A] = Human carcinogen based on adequate evidence from human studies.
[B2] = Probable human carcinogen based on inadequate evidence from human studies and adequate evidence from animal studies;
[C] = Possible human carcinogen based on limited evidence from animal studies in the absence of human studies.
(d) Factor that reflects the uncertainty in the estimated RfD. Larger factors are associated with greater uncertainty.
(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, an organ or system known to be affected by the chemical is listed.
(f) Value reported is cadmium ingested with water.
(g) RfD reported is for chromium VI, as all chromium is conservatively assumed to be in the more toxic form of chromium VI.
(h) The hazard index is the sum of the CDI:RfD ratios for the chemicals listed.

Aquatic Life. Impacts to aquatic invertebrates and fish were evaluated by comparing surface water and sediment concentrations in various surface waters with ambient water quality criteria (AWQC), State water quality standards, and other toxicity data. Based on these comparisons it is apparent that aquatic life at MAAP may be adversely impacted by elevated concentrations of inorganic chemicals in surface water and sediment.

2.5 BASELINE RISK ASSESSMENT OF GROUNDWATER IN THE O-LINE PONDS AREA

In accordance with the NCP, a baseline risk assessment was performed using the data collected during the FS field work, and using the future residential land use scenario for the O-Line Ponds area. Under this assumption, future residents would be exposed to the contaminants detected in groundwater via ingestion. This second risk assessment supplements the results of the RI risk assessment summarized in Section 2.4.

Homeowners in this area of western Tennessee tend not to install drinking water wells deeper than necessary to obtain sufficient quantities of water. The high permeability of the Memphis Sand aquifer results in adequate well yield even at shallow depths within the aquifer. Therefore, the assumption was made in this baseline risk assessment that on-site residents would be exposed to levels of contaminants immediately downgradient from the O-Line Ponds and shallow within the aquifer. The two wells corresponding to these conditions are MI001 and MI058.

Both wells were sampled during the RI; however, the samples were analyzed only for explosive compounds and select metals. In the interest of evaluating the risk posed by all organic and inorganic constituents within the shallow aquifer, the wells were resampled in January 1992 and analyzed for TCL VOCs, BNAs, pesticides, herbicides, PCBs, explosives, and TAL inorganic analytes including cyanide. These data present the most complete and up-to-date picture of conditions immediately downgradient from the O-Line Ponds. Therefore, these data were used in developing the baseline risk assessment for groundwater.

2.5.1 Chemicals Of Potential Concern

This section briefly summarizes available groundwater monitoring data collected at the O-Line Ponds area and identifies chemicals of potential concern for further evaluation in the baseline risk assessment. Chemicals of potential concern are defined as those chemicals believed to be associated with past activities at the site. Table 2-9 summarizes the chemicals of potential concern for wells MI001 and MI058. Duplicate samples were averaged together and the concentration reported for each well is the arithmetic mean of the reported values.

As shown in Table 2-9, a total of 11 organic chemicals and 13 inorganic chemicals were detected in the two monitoring wells. Nine and 11 organic chemicals were selected as chemicals of potential concern in wells MI001 and MI058, respectively. Additionally, a total of 13 and 10 inorganic chemicals were selected in wells MI001 and MI058, respectively. The groundwater data for these wells are presented in Appendix B.

Of the organic compounds selected as chemicals of potential concern, three were detected at the highest concentrations in both monitoring wells MI001 and MI058: HMX (1,200 μg/L and 1,100 μg/L, respectively), RDX (6,400 μg/L and 7,800 μg/L, respectively), and 2,4,6-TNT (6,500 μg/L and 15,500 μg/L, respectively). 1,3,5-Trinitrobenzene was also present in significant quantities in well MI058. Several other organic chemicals were detected (at levels less than 750 μg/L), and these other organic chemicals are included in the risk assessment. Of the inorganic chemicals selected as chemicals of potential concern, the 6 essential nutrients (aluminum, calcium, iron, magnesium, potassium and sodium) were detected at the greatest concentrations. Barium and manganese were also detected at significant concentrations in

Table 2-9

CHEMICALS OF POTENTIAL CONCERN IN GROUNDWATER
IMMEDIATELY DOWNGRADIENT OF THE O-LINE PONDS
(ug/L)

	Well MI001 (a)	Well MI058 (a)
Organics (b):		
* Carbon Disulfide (CS2)	9.00E+00	3.50E+00
* 1,3-Dinitrobenzene (13DNB)	7.80E+01	7.95E+01
* 2,4-Dinitrotoluene (24DNT)	6.60E+01	1.80E+02
* 2,6-Dinitrotoluene (26DNT)	1.60E+01	1.00E+01
* HMX (HMX)	1.20E+03	1.10E+03
* Nitrobenzene (NB)	3.58E+01	1.53E+01
* 2-Propanol (2-PROL)	ND	7.00E+00
* RDX (RDX)	6.40E+03	7.80E+03
* 1,1,2,2-Tetrachloroethane (TCLEA)	ND (<1)	2.67E+00
* 1,3,5-Trinitrobenzene (135TNB)	7.50E+02	2.15E+03
* 2,4,6-Trinitrotoluene (246TNT)	6.50E+03	1.55E+04
Inorganics:		
* Aluminum (AL)	1.90E+03	9.61E+01
* Barium (BA)	2.37E+02	1.09E+02
* Calcium (CA)	8.98E+03	2.08E+04
* Cyanide (CYN)	1.43E+01	4.08E+01
* Iron (FE)	1.05E+03	6.95E+01
* Lead (PB)	1.25E+00	ND (<1)
* Magnesium (MG)	2.97E+03	6.93E+03
* Manganese (MN)	5.96E+02	1.08E+03
* Mercury (HG)	1.00E+00	ND (<0)
* Potassium (K)	1.71E+03	3.17E+03
* Sodium (NA)	6.03E+05	6.05E+03
* Vanadium (V)	8.75E+00	ND (<11)
* Zinc (ZN)	3.90E+01	3.70E+01

* = Selected as a chemical of potential concern.
ND = Not detected. Detection limit provided in parentheses.

(a) Concentrations reported in duplicate samples were averaged together.
(b) USATHAMA chemical codes are listed in parentheses.

both wells (109 to 237 μg/L and 596 to 1,080 μg/L, respectively). All other inorganic chemicals selected were detected at levels less than 40.8 μg/L.

2.5.2 Exposure Assessment

In this section, the potential pathways by which populations may be exposed to the chemicals of potential concern in groundwater are identified and exposure is quantified. This risk assessment focuses solely on potential human health risks associated with ingestion of untreated groundwater from the monitoring wells MI001 and MI058. Neither of these wells is currently being used as a drinking water source and the threat of future exposures is very unlikely. Nevertheless, future residential use will be evaluated to satisfy regulatory concerns.

Groundwater monitoring data indicate that chemicals have been released to and are being transported in groundwater. Persons using untreated groundwater as a domestic water supply could be exposed to chemicals in groundwater via ingestion of drinking water. However, under current land-use conditions, there is no use of untreated groundwater by residents or other individuals; therefore, no complete exposure pathways exist. Under future land-use conditions, potential exposures and risks associated with ingestion of groundwater are being evaluated to provide a risk-based measure of the extent of contamination associated with the suspected source area.

Chronic daily intakes (CDIs) are calculated for residential drinking water exposures using the estimated exposure point concentrations presented in Table 2-9 and exposure parameters presented in Table 2-10. A reasonable maximum exposure (RME) case was evaluated in accordance with EPA guidance. It was assumed that chemical concentrations in the monitoring wells would remain constant over the duration of the exposure period. CDIs were estimated using the equation and assumptions presented below for groundwater ingestion:

$$CDI=\frac{Cw*IR*EF*ED}{BW*AT*Days}$$

where

CDI	=	chronic daily intake (mg/kg-day),
C_w	=	chemical concentration in groundwater (mg/l),
IR	=	water ingestion rate (l/day),
EF	=	frequency of exposure (days/year),
ED	=	duration of exposure (years),
BW	=	average body weight (kg),
AT	=	averaging time (70 years for carcinogens, 30 years for noncarcinogens), and
Days	=	conversion factor (365 days/year).

Drinking water exposures are evaluated for a resident between the ages of 0 through 30. For persons 0-30 years of age, a time-weighted average body weight of 48 kg (based on data in USEPA 1989d), and a drinking water rate of 1.9 liters/day are used as parameters for the reasonable maximum exposure (RME) case. The drinking water consumption rate has been calculated assuming a consumption rate of 1 liter/day for individuals up to 10 kg (approximately 3 years of age), and a rate of 2 liters/day for persons over 3 years of age. An exposure duration of 30 years, the upper-bound time at one residence, is assumed for residents (USEPA 1991, 1989a).

CDIs calculated using these exposure assumptions for chemicals exhibiting carcinogenic effects and chemicals exhibiting noncarcinogenic effects due to ingestion of groundwater from the site are presented in Table 2-11.

Table 2-10
Exposure Parameters for Ingestion of Groundwater
Under the Residential Land Use Scenario

Parameter	Reasonable Maximum Exposure (RME) Value 0-30 Year Old Resident
Exposure Frequency (days/year) (a)	350
Exposure Duration (years) (b)	30
Ingestion Rate (liters/day) (c)	1.9
Body Weight (kg) (d)	48
Averaging Time (years)	
Carcinogenic (e)	70
Noncarcinogenic	30

(a) The value for resident is the standard default value recommended by EPA (1991).
(b) Value for residents is based on the upper-bound time at one residence (USEPA 1991, 1989a).
(c) Value for 0-30 year old is the weighted-average drinking water intake: 1 liter/day up to 10 kg body weight (approximately 3 years), and 2 liters/day for persons over three years of age (USEPA 1989d).
(d) A time weighted-average for a 0-30 years old, based on data provided in EPA (1989d).
(e) Based on EPA (1991, 1989a) standard assumption for lifetime.

Table 2-11

ESTIMATED EXPOSURE POINT CONCENTRATIONS AND CDIs

Chemical	Well MI001 Exposure Point Concentration (ug/L)	Well MI058 Exposure Point Concentration (ug/L)	Well MI001 Chronic Daily Intake (mg/kg-day) (b)	Well MI058 Chronic Daily Intake (mg/kg-day) (b)
Chemicals Exhibiting Carcinogenic Effects				
Organics:				
2,4-Dinitrotoluene (24DNT)	6.60E+01	1.80E+02	1.1E-03	2.9E-03
2,6-Dinitrotoluene (26DNT)	1.60E+01	1.00E+01	2.6E-04	1.6E-04
RDX (RDX)	6.40E+03	7.80E+03	1.0E-01	1.3E-01
1,1,2,2-Tetrachloroethane (TCLEA)	ND (<1)	7.00E+00	NA	1.1E-04
2,4,6-Trinitrotoluene (246TNT)	6.50E+03	1.55E+04	1.1E-01	2.5E-01
Chemicals Exhibiting Noncarcinogenic Effects				
Organics:				
Carbon Disulfide (CS2)	9.00E+00	3.50E+00	3.4E-04	1.3E-04
1,3-Dinitrobenzene (13DNB)	7.80E+01	7.95E+01	3.0E-03	3.0E-03
HMX (HMX)	1.20E+03	1.10E+03	4.6E-02	4.2E-02
Nitrobenzene (NB)	7.10E+01	3.00E+01	2.7E-03	1.1E-03
RDX (RDX)	6.40E+03	7.80E+03	2.4E-01	3.0E-01
1,1,2,2-Tetrachloroethane (TCLEA)	ND (<1)	7.00E+00	NA	2.7E-04
1,3,5-Trinitrobenzene (13TNB)	7.50E+02	2.15E+03	2.8E-02	8.2E-02
2,4,6-Trinitrotoluene (246TNT)	6.50E+03	1.55E+04	2.5E-01	5.9E-01
Inorganics:				
Barium (BA)	2.37E+02	1.09E+02	9.0E-03	4.2E-03
Cyanide (CYN)	2.70E+01	4.08E+01	1.0E-03	1.5E-03
Manganese (MN)	5.96E+02	1.08E+03	2.3E-02	4.1E-02
Mercury (HG)	1.00E+00	ND (<0)	3.8E-05	NA
Vanadium (V)	1.20E+01	ND (<11)	4.6E-04	NA
Zinc (Zn)	3.90E+01	3.70E+01	1.5E-03	1.4E-03

ND = Not detected. Detection limit provided in parentheses.
NA = Not applicable. CDI not calculated because this chemical was not selected as a chemical of potential concern in this well.

(a) CDIs are calculated only for chemicals of potential concern with oral toxicity criteria. The following chemicals of potential concern are not presented due to lack of toxicity criteria: aluminum, calcium, iron, lead, magnesium, potassium, 2-propanol, and sodium.
(b) See text for exposure assumptions.

2.5.3 Toxicity Assessment

Section 9.3 of the Remedial Investigation Report (USATHAMA, 1991c) presents the general methodology for classifying the health effects of toxic chemicals and for developing health effects criteria. Table 2-12 presents chronic oral health effects criteria (slope factors and RfDs) for the chemicals of potential concern to be quantitatively evaluated in this assessment.

No oral health effects criteria are available for aluminum, calcium, iron, lead, magnesium, potassium, 2-propanol and sodium, therefore, potential risks associated with ingestion of these chemicals will not be quantitatively evaluated. Exclusion of these chemicals from the quantitative evaluation is not anticipated to result in significant underestimates of risk. The essential nutrients (aluminum, calcium, iron, magnesium, potassium, and sodium) are not likely to pose adverse health effects at the concentrations present in groundwater within the O-Line Ponds area. Furthe the limited toxicity information that is available for 2-propanol suggests that this chemical . nerally ca be considered less toxic than the other chemicals of potential concern at the O-Line Ponds area for which health effects criteria are available. In addition, this chemical was used in the field equipment decontamination process and is therefore most likely an artifact of sampling. Lead will be evaluated qualitatively in the Risk Characterization Section below.

2.5.4 Risk Characterization

As outlined previously in Section 2.4.3, risk estimates were calculated by combining chronic daily intakes (CDIs) for residents ingesting groundwater with reference doses (RfDs) or slope factors (SF) to derive noncarcinogenic hazard indices or excess lifetime cancer risks. For carcinogens, potential risks are presented as the product of the CDI and slope factors. Risks were compared to EPA's target risk range of 10^{-4} to 10^{-6}. For noncarcinogens, potential hazards are presented as the ratio of the CDI to the reference dose (CDI:RfD), and the sum of the ratios is referred to as the hazard index. In general, hazard indices that are less than one are not likely to be associated with adverse health effects, and are therefore less likely to be of regulatory concern than hazard indices greater than one.

Carcinogenic and noncarcinogenic risks associated with the ingestion of untreated groundwater from monitoring wells MI001 and MI058 by future residents are presented in Table 2-13. The estimated upper bound excess lifetime cancer risks for ingestion of groundwater from MI001 is 1×10^{-2}. This risk exceeds EPA's target risk range of 10^{-6} to 10^{-4} range for human health protectiveness, and is due primarily to RDX and 2,4,6-TNT, although 2,4-DNT and 2,6-DNT also contributed to the elevated risks. The excess lifetime cancer risk for a future resident ingesting groundwater from MI058 is 2×10^{-2} as presented in Table 2-13. This value exceeds EPA's risk range for human health protectiveness. The primary chemicals contributing to this risk are RDX, 2,4,6-TNT and 2,4-DNT. As stated previously in Section 2.4.3, it is important to note that RDX and 2,4,6-TNT are Class C carcinogens, and therefore their carcinogenic risks could be over-estimated. For noncarcinogenic chemicals, the hazard index exceeded one for both MI001 (HI= 1,000) and MI058 (HI= 3,000) due to 1,3-DNB, nitrobenzene, RDX, 1,3,5-TNB and 2,4,6-TNT.

The highest detected concentration of lead was 1.25 μg/L in monitoring well MI001. This concentration is less than the suggested EPA final "clean-up" level of 15 μg/L for lead in groundwater (USEPA, 1990b). Groundwater concentrations of 15 μg/L lead are considered protective by EPA (1990) and are likely to correlate with blood lead levels below 10 μg/L in roughly 99 percent of young children who are not exposed to excessive lead paint hazards or heavily contaminated soils. Therefore, the lead concentrations in groundwater in well MI001 is not likely to contribute to the overall risk to residents.

2.5.5 Baseline Risk Assessment Summary

The following conclusions may be drawn from the risk analysis presented above:

Table 2-12

CHRONIC ORAL HEALTH EFFECTS CRITERIA (SLOPE FACTORS AND RFDs) AND ESTIMATED CARCINOGENIC AND NONCARINOGENIC RISKS

Chemical	Chronic RfD mg/kg-day	Uncertainty Factor (b)	Toxicological Endpoint (c)	Source	Slope Factor (mg/kg-day)-1	Weight-of-Evidence (d)	Source
Organics:							
Carbon disulfide	1E-01	100	Fetotoxicity	IRIS	---	---	---
1,3-Dinitrobenzene	1E-04	3,000	Spleen	IRIS	---	D	IRIS
2,4-Dinitrotoluene	---	---	---	IRIS	6.8E-01	B2	HEAST
2,6-Dinitrotoluene	---	---	---	HEAST	6.8E-01	B2	HEAST
HMX	5E-02	1,000	Liver	IRIS	---	---	---
Nitrobenzene	5E-04	10,000	Liver/Kidney	IRIS	---	D	IRIS
RDX	3E-03	100	Prostate	IRIS	1E-01	C	IRIS
1,1,2,2-Tetrachloroethane	4.6E-04	1,000	Liver/WBC	(e)	2E-01	C	IRIS
1,3,5-Trinitrobenzene	5E-05	10,000	Spleen	IRIS	---	---	---
2,4,6-Trinitrotoluene	5E-04	1,000	Liver	IRIS	3E-02	C	IRIS
Inorganics:							
Barium	7E-02	3	Inc. Blood Pressure	IRIS	---	---	---
Cyanide	2E-02	5,000	Neurological	IRIS	---	---	---
Mercury	3E-04	1,000	Kidney	HEAST	---	D	IRIS
Manganese	1E-01	1	Neurological	IRIS	---	---	---
Vanadium	7E-03	100	Liver/Kidney	HEAST	---	---	---
Zinc	2E-01	10	Anemia	HEAST	---	---	---

(a) The following chemicals are not presented because they lack toxicity criteria: aluminum, calcium, iron, lead, magnesium, potassium, 2-proponal, and sodium.

(b) Uncertainty factors used to develop reference doses generally consist of multiples of 10, with each factor representing a specific area of uncertainty in the data available. The standard uncertainty factors include the following:
- A 10-fold factor to account for the variation in sensitivity among the members of the human population;
- A 10-fold factor to account for the uncertainty in extrapolation animal data to the case of humans;
- A 10-fold factor to account for uncertainty in extrapolating from less than chronic NOAELs to chronic NOAELs; and
- A 10-fold factor to account for the uncertainty in extrapolating from LOAELs to NOAELs.

(c) A target organ is the organ most sensitive to a chemical's toxic effect. RfD's are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, an organ or system known to be affected by the chemical is listed.

(d) EPA Weight of Evidence for Carcinogenic Effects:
[B2] = Probable human carcinogen based on inadequate evidence from human studies and adequate evidence from animal studies;
[C] = Possible human carcinogen based on limited evidence from animal studies in the absence of human studies; and
[D] = Not classified as to human carcinogenicity.

(e) Interim RfD approved by ECAO, Cincinnati.

NOTE: IRIS = Integrated Risk Information System, January 1992.
HEAST = Health Effects Assessment Summary Tables, Annual 1991.
--- = No information available.

Table 2-13

POTENTIAL RISKS ASSOCIATED WITH INGESTION OF GROUNDWATER
BY FUTURE RESIDENTS UNDER THE RESIDENTIAL LAND USE SCENARIO (a)

Chemicals Exhibiting Carcinogenic Effects (c)	Well MI001 Chronic Daily Intake (CDI) (mg/kg-day)	Well MI058 Chronic Daily Intake (CDI) (mg/kg-day)	Cancer Slope Factor (mg/kg-day)-1	Weight of Evidence (b)	Well MI001 Upper Bound Excess Lifetime Cancer Risk	Well MI058 Upper Bound Excess Lifetime Cancer Risk
Organics:						
2,4-Dinitrotoluene (24DNT)	1.1E-03	2.9E-03	6.8E-01	[B2]	7E-04	2E-03
2,6-Dinitrotoluene (26DNT)	2.6E-04	1.6E-04	6.8E-01	[B2]	2E-04	1E-04
RDX (RDX)	1.0E-01	1.3E-01	1.1E-01	[C]	1E-02	1E-02
1,1,2,2-Tetrachloroethane (TCLEA)	NA	1.1E-04	2E-01	[C]	NA	2E-05
2,4,6-Trinitrotoluene (246TNT)	1.1E-01	2.5E-01	3E-02	[C]	3E-03	8E-03
Total					1E-02	2E-02

Chemicals Exhibiting Noncarcinogenic Effects (c)	Well MI001 Chronic Daily Intake (CDI) (mg/kg-day)	Well MI058 Chronic Daily Intake (CDI) (mg/kg-day)	Reference Dose (mg/kg-day) [Uncertainty Factor] (d)	Toxicological Endpoint (e)	Well MI001 Risk CDI:RfD Ratio	Well MI058 Risk CDI:RfD Ratio
Organics:						
Carbon Disulfide (CS2)	3.4E-04	1.3E-04	1E-01 [100]	fetotoxicity	3E-03	1E-03
1,3-Dinitrobenzene (13DNB)	3.0E-03	3.0E-03	1E-04 [3,000]	spleen	3E+01	3E+01
HMX (HMX)	4.6E-02	4.2E-02	5E-02 [1,000]	liver	9E-01	8E-01
Nitrobenzene (NB)	2.7E-03	1.1E-03	5E-04 [10,000]	liver/kidney	5E+00	2E+00
RDX (RDX)	2.4E-01	3.0E-01	3E-03 [100]	prostate	8E+01	1E+02
1,1,2,2-Tetrachloroethane (TCLEA)	NA	2.7E-04	4.6E-04 [1,000]	liver, WBC	NA	6E-01
1,3,5-Trinitrobenzene (135TNB)	2.8E-02	8.2E-02	5E-05 [10,000]	spleen	6E+02	2E+03
2,4,6-Trinitrotoluene (246TNT)	2.5E-01	5.9E-01	5E-04 [1,000]	liver	5E+02	1E+03
Inorganics:						
Barium (BA)	9.0E-03	4.2E-03	7E-02 [3]	> blood pressure	1E-01	6E-02
Cyanide (CYN)	1.0E-03	1.5E-03	2E-02 [500]	neurological	5E-02	8E-02
Manganese (MG)	2.3E-02	4.1E-02	1E-01 [1]	neurological	2E-01	4E-01
Mercury (HG)	3.8E-05	NA	3E-04 [1,000]	kidney	1E-01	NA
Vanadium (V)	4.6E-04	NA	7E-03 [100]	liver, kidney	7E-02	NA
Zinc (Zn)	1.5E-03	1.4E-03	2E-01 [10]	anemia	7E-03	7E-03
Hazard Index					1E+03	3E+03

NA = Not applicable. CDI not calculated because this chemical was not selected as a chemical of potential concern in this well.

(a) Risks are calculated for those chemicals of potential concern with toxiciy criteria.
(b) USEPA Weight of Evidence for Carcinogenic Effects:
[B2] Probable human carconogen based on inadequate evidence from human studies and adequate evidence from animal studies;
[C] Possible human carcinogen based on limited evidence from animal studies in the absence of human studies.
(c) USATHAMA chemical codes are listed in parentheses.
(d) Uncertainty factors represent the amount of uncertainty in extrapolation from the available data.
(e) Toxological endpoints are endpoints most likely given a chemical's toxic effects. RfDs are based on toxic effects in the toxological endpoint. If an RfD were based on a study in which a toxological endpoint were not identified, the endpoint listed is one known to be affected by the particular chemical of concern.

- Groundwater contamination associated with past use of the O-Line Ponds does not pose any short-term risk to human health or the environment under current land use conditions;

- Human health impacts are possible, however, if the O-Line Ponds area is developed for residential use and groundwater is used as a source of drinking water;

- Carcinogenic risk under the future residential land use scenario is due principally to the presence of high levels of explosive compounds in shallow groundwater immediately downgradient of the O-Line Ponds;

- Adverse health effects posed by noncarcinogens under the future residential land use scenario are due principally to explosive compounds;

- The other organic compounds detected in groundwater (carbon disulfide, 2-propanol, and 1,1,2,2-tetrachloroethane) were found at low levels. 2-Propanol was used in the field decontamination process; and

- The inorganic analytes were not detected at levels significantly higher than background levels for the region.

The risk assessment indicates that groundwater quality in the O-Line Ponds area has been impacted and that use of this groundwater for drinking water would result in significant human health risks. The removal of explosive compounds from groundwater will reduce the overall carcinogenic and noncarcinogenic risks to acceptable levels. The risk assessment also indicates that levels of inorganic constituents are not high enough to cause adverse human health effects; therefore, these levels may be re-injected into the aquifer.

3.0 REMEDIAL ACTION OBJECTIVES

Remedial action objectives based on human health and environmental considerations drive the formulation and development of response actions. Such objectives are developed based on criteria outlined in Section 300.68(e)(2) of the NCP and Section 121 of SARA.

The remedial action objectives for MAAP have been developed in such a way that attainment of these goals will result in the short- and long-term protection of human health and the environment. These objectives will be specific to contaminated groundwater emanating from the O-Line Ponds Area, but are not so limited that the choice of remedial technologies is overly restricted. Because the remedial action objectives focus on the exposure pathways of concern identified by the RI risk assessment and the baseline risk assessment (Section 2.0) and include attainment of ARARs; thus, the contaminants of concern, the exposure route and receptors, and the acceptable contaminant level for each exposure route are addressed.

For the focused FS of groundwater treatment alternatives, acceptable concentrations of contaminants in treated effluent will be set such that the applicable or relevant and appropriate requirements (ARARs) listed in the RI report (USATHAMA, 1991c) are met or exceeded. These potential ARARs and to-be-considered guidance are described below. In addition to the chemical-specific ARARs and to-be-considered values, remedial response objectives also consider the following criteria:

- Whether the remediation goals for all carcinogens of concern provide protection within the risk range of 10^{-4} to 10^{-6};
- Whether the remediation goals set for all non-carcinogens of concern are sufficiently protective;
- Whether environmental effects are adequately addressed; and
- Whether the exposure analysis adequately addresses each human exposure pathway identified in the baseline risk assessment.

The baseline risk assessment for Operable Unit I identified ingestion of groundwater as the primary pathway of concern. The risk associated with this pathway is unacceptably large; therefore, the target remediation concentrations of contaminants correspond to those which do not pose adverse health effects. Current conditions (contaminated groundwater emanating from the O-Line Ponds area) do not appear to pose significant environmental risks. Based on this scenario, the remedial action objectives are to provide remediation of contaminated groundwater in the O-Line Ponds area so that:

- Risks associated with groundwater ingestion are controlled;
- Environmental systems in the vicinity are protected; and
- Potential human health risks associated with continued migration of contaminated groundwater are controlled.

3.1 IDENTIFICATION OF APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Section 121 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), requires that remedial actions at Superfund sites comply with requirements or standards under Federal

or State environmental laws that are "applicable" or "relevant and appropriate" (ARAR) to the hazardous substances, pollutants, or contaminants at a site or the circumstances of the release. ARARs are defined as cleanup standards, standards of control, and other substantive environmental protection requirements, criteria or limitations promulgated under Federal or State law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a Superfund site. ARARs are used to develop remedial action objectives, determine the appropriate extent of site cleanup, and govern implementation and operation of the selected action.

SARA amended Section 121 of CERCLA to include the following waivers for ARARs. Provided that the remedial action protects human health and the environment, requirements may be waived if:

- The remedial action is an interim measure where the final remedy will attain the ARAR upon completion;
- Compliance will result in greater risk to human health and the environment than other options;
- Compliance is technically impracticable;
- An alternative remedial action will attain the equivalent of the ARAR;
- For State requirements, the State has not consistently applied the State requirement in similar circumstances; or
- For Section 104 remedial actions, compliance with the ARAR will not provide a balance between protecting human health, welfare, and the environment at the facility with the availability of Fund money for response at other facilities (this waiver is not applicable at MAAP).

"Applicable" requirements are those federal and state requirements which are legally applicable, whether directly or incorporated by a federally-authorized state program. "Relevant and appropriate" requirements are federal and state standards, criteria, or limitations which are not legally applicable to the site, but which address problems so similar that their application is appropriate. The determination that a requirement is relevant and appropriate involves the comparison of a number of site specific factors with those addressed in the regulatory requirements, including the physical circumstances of the site, hazardous substances present at the site, and characteristics of the remedial action. To-be-considered materials (TBCs) are non-promulgated advisories or guidance issued by Federal or State government that are not legally binding and do not have the status of ARARs. TBCs may be used in conjunction with ARARs to determine the necessary level of cleanup for protection of health and the environment.

Selection of ARARs is dependent on the hazardous substances present at the site, the site characteristics and location, and the actions selected for a remedy. Thus, these requirements may be chemical-, location-, or action-specific. Chemical-specific ARARs are health- or risk-based concentration limits set for specific hazardous substances, pollutants, or contaminants in various environmental media. These requirements provide protective site cleanup levels, or a basis for calculating cleanup levels, for chemicals of concern in the designated media. Chemical-specific ARARs are also used to indicate an acceptable level of discharge to determine treatment and disposal requirements for a particular remedial activity and to assess the effectiveness of a remedial alternative. In the event that a chemical has more than one requirement, the most stringent of the requirements is applied.

Location-specific ARARs set restrictions on the types of remedial activities which can be performed based on site-specific characteristics or location. Alternative remedial actions may be restricted or

precluded based on federal or state siting laws for hazardous waste facilities, and proximity to wetlands or floodplains or to man-made features such as existing landfills, disposal areas, and local historic buildings. Location-specific ARARs provide a basis for assessing restrictions during the formulation and evaluation of potential site-specific remedies.

Action-specific ARARs set controls or restrictions on the design, implementation, and performance of waste management actions. They are based on specific remedial activities which may be selected to accomplish cleanup objectives. After remedial alternatives are developed, action-specific ARARs which specify performance levels, actions, or technologies, as well as specific levels for discharge or residual chemicals, provide a basis for assessing the feasibility and effectiveness of the remedial alternatives. The regulatory agencies responsible for the site make the final determination on the applicability or relevance and appropriateness of a requirement based on such factors as the characteristics of the remedial action and physical circumstances of the site.

3.2 CHEMICAL-SPECIFIC ARARs

The chemicals of concern identified during the RI are those inorganic analytes which were detected above background levels and all organic compounds detected at the site. The chemicals of concern for this FS consist of those chemicals which were detected in the O-Line Ponds groundwater plume.

3.2.1 Groundwater Criteria

3.2.1.1 Applicable or Relevant and Appropriate Requirements. EPA has developed chemical-specific criteria that may be considered ARARs at MAAP. These criteria are the National Primary Drinking Water Standards (NPDWS), which are codified in 40 CFR Part 141. The NPDWS include maximum contaminant levels (MCLs) and maximum contaminant level goals (MCLGs).

MCLGs were developed under the Safe Drinking Water Act as chemical-specific health goals used in setting enforceable drinking water standards for public water supply systems. MCLGs are based entirely on health considerations and do not take cost or feasibility into account. As health goals, MCLGs are set at levels where no known or anticipated health effects may occur, including an adequate margin of safety. EPA is required to set MCLs as close as feasible to the respective MCLG, taking into consideration the best technology, treatment techniques, and other factors (including cost). However, as the standard for public water supplies, MCLs are fully protective of human health and (for carcinogens) fall within the target risk range of 10^{-4} to 10^{-6}. Furthermore, for noncarcinogens, which are the majority of contaminants, MCLs are almost always set at the same level as the respective MCLGs. These standards assure that even sensitive populations will experience no adverse health effects (52 Federal Register 33499).

The use or potential use of the groundwater (potable or potentially potable) must be considered in determining potential ARARs. According to the previously cited guidance, MCLs will generally be considered ARARs for all Federal Class I and Class II groundwater or surface water that is or may be used for drinking water.

The State of Tennessee has promulgated groundwater standards under Chapter 1200-5-1-.06 of the Rules of the Tennessee Department of Health and the Environment, as amended. Where the State standards are different from Federal MCLs, the more stringent requirement will generally be selected.

Secondary maximum contaminant levels (SMCLs) were developed under the Safe Drinking Water Act as chemical-specific reasonable goals for drinking water quality. They apply to any contaminant in

drinking water which may adversely affect the odor, aesthetics or appearance. SMCLs are regarded as "other guidance".

A list of potential chemical-specific ARARs for groundwater is presented in Table 3-1. Also listed are criteria, advisories, and guidance available for groundwater. The chemical-specific standards, advisories, and criteria are listed in Table 3-2 for all analytes detected above their respective background concentrations during the Remedial Investigation (USATHAMA, 1991).

3.2.1.2 Other Guidance To Be Considered. In the absence of Federal or State-promulgated ARARs, EPA states a preference for Office of Drinking Water Health Advisories (HAs) and Reference Doses (RfDs) for systemic toxicants, and cancer slope factors (CSFs) for carcinogens (53 FR 41566, October 10, 1989).

EPA provides drinking water suppliers with guidance on various chemicals that may be encountered in a water system which are known as health advisories. The Office of Drinking Water's non-regulatory health advisories are concentrations of contaminants in drinking water at which adverse effects would not be anticipated to occur. A margin of safety is included to protect sensitive members of the population. The health advisory numbers are developed from data describing noncarcinogenic end-points of toxicity. They do not incorporate quantitatively any potential carcinogenic risk from such exposure. Lifetime health advisories are calculated for a 70-kg adult assumed to drink 2 liters of water per day.

For the remaining contaminants of concern, risk-based chemical remediation target levels will be developed using RfDs and CSFs from the EPA Integrated Risk Information System (IRIS) database. For carcinogens and suspected carcinogens, target levels are calculated using the assumptions of a 70-kg human and a lifetime ingestion of 2 liters of water per day, and correspond to an excess cancer risk of 10^{-6}. For non-carcinogens, target levels will be set equal to the concentration that will result in no adverse health effects following ingestion of contaminated drinking water. RfDs and CSFs are available from the EPA "Integrated Risk Information System (IRIS), and are listed in Table 3-3 for chemicals at MAAP. Where promulgated Federal and State standards have not been developed for the chemicals of concern at MAAP, and where HAs or U.S. Army-proposed risk values are not available, health-based guidance values have been calculated and are shown in Table 3-3.

3.2.2 Surface Water Criteria

There is no evidence that the O-Line Ponds are having a direct effect on surface water quality at the present time. However, it is possible that future groundwater remediation operations may involve discharge into either a ditch where the presence of water is intermittent, or directly into a perennial surface water body, such as the Rutherford Fork. Therefore, Federal and State surface water criteria may be ARARs. Potential chemical-specific ARARs for surface water are presented in Table 3-4. Chemical-specific criteria for all analytes detected above background concentrations during the RI are listed in Table 3-5. Values are not available for many organic contaminants of concern.

Federal ambient water quality criteria (AWQC) for the protection of aquatic organisms have been established by EPA under the Clean Water Act. These criteria are available for both organic and inorganic contaminants.

The State of Tennessee has proposed general water quality criteria under the Rules of the Tennessee Department of Health and Environment, Chapter 1200-4-3. Also applicable under these Rules are the use designations for surface water. The State has designated the Rutherford Fork of the Obion River, Wolf Creek, East Fork of Wolf Creek, and the tributary to mile 27.7 of the Rutherford Fork for the

TABLE 3-1
Identification of Potential ARARs and To-Be-Considered Guidance for Groundwater

Authority	Requirement	Status	Requirement Synopsis
Federal Regulatory Requirement	Safe Drinking Water Act (SDWA) - Maximum Contaminant Levels (MCLs), 40 CFR 141.11-141.16	Relevant and Appropriate	MCLs have been promulgated for a number of common organic and inorganic contaminants. These levels regulate the concentration of contaminants in public drinking water supplies based on health effects and technical capabilities. MCLs may also be considered relevant and appropriate for groundwater aquifers potentially used for drinking water.
State Regulatory Requirements	Rules of the Tennessee Department of Health and the Environment, Chapter 1200-5-1-.06	Relevant and Appropriate	The State of Tennessee has adopted groundwater standards and public water supply standards.
Federal Criteria, Advisories, and Guidance	SDWA - Maximum Contaminant Level Goals (MCLGs)	To Be Considered	MCLGs are health-based criteria that are to be considered for drinking water sources as a result of SARA. These goals are available for a number of organic and inorganic contaminants.
	EPA Carcinogen Assessment Group Potency Factors	To Be Considered	Potency factors are developed by EPA from health effects assessments or evaluation by the Carcinogen Assessment Group. Carcinogen potency factors are used in the baseline risk assessment to compute the individual incremental cancer risk resulting from exposure to site contaminants.
	EPA Office of Drinking Water Health Advisories (HAs)	To Be Considered	Health advisories developed from estimates of risk due to consumption of contaminated drinking water considering noncarcinogenic effects only. Health advisories are considered for contaminants in groundwater that may be used for drinking water.
	EPA Risk Reference Doses (RfDs)	To Be Considered	RfDs are dose levels developed by EPA for non-carcinogenic effects. RfDs are used in the baseline risk assessment to characterize risks due to exposure to non-carcinogenic contaminants in groundwater.

TABLE 3-2
Potential Chemical-Specific ARARs and To-Be-Considered Guidance for Contaminants Detected in Groundwater Above Background Concentrations During the RI

Analyte	State of Tennessee[1] (mg/L)		Federal (mg/L)				U.S. Army Surgeon General Permissible Drinking Water Criteria (mg/L)	Proposed by the U.S. Army (Etnier, 1987) 10^{-6} risk (mg/L)
	Groundwater Standard	Public Water Supply Standard	MCL	MCLG	Lifetime Health Advisory	SMCL		
Acetone	--	--	--	--	--	--	--	--
Aluminum	--	--	--	--	--	0.050-0.200 (b)	--	--
Arsenic	0.05	0.05	0.05 (a)	0.05 (P,h)	--	--	--	--
Barium	--	1.0	1.0 (a,an) 2.0 (i,an)	2.0 (i)	2.0 (d)	--	--	--
bis(2-ethylhexyl) phthalate	--	--	0.004 (P,c)	0 (P,c)	--	--	--	--
Cadmium	0.01	0.01	0.005 (b)	0.005 (b)	0.005 (b)	--	--	--
Chloroform	--	--	0.10 (a,j)	--	--	--	--	--
Chromium	0.05	0.05	0.1 (b)	0.1 (b)	0.12 (e)	--	--	--
Copper	--	1.0	1.3 (k)	1.3 (k)	--	1.0 (f)	--	--
Cyanide	--	--	0.20	0.20	--	--	--	--
1,3-DNB	--	--	--	--	0.001 (d)	--	--	--
2,4-DNT	--	--	--	0	--	--	--	0.00017
2,6-DNT	--	--	--	0	--	--	--	0.0000068
Ethylbenzene	--	--	0.70 (b)	0.70 (b)	0.68 (e)	0.03 (P,g)	--	--
HMX	--	--	--	--	0.4 (z)	--	--	--
Lead	0.05	0.05	0.05 (a,am) 0.015 (AL,k)	0.0 (k)	--	--	--	--
Manganese	--	0.05	--	--	--	0.05 (f)	--	--
Mercury	0.002	0.002	0.002 (b)	0.002 (b)	0.002 (d)	--	--	--

TABLE 3-2 (Cont'd)
Potential Chemical Specific ARARs and To-Be-Considered Guidance for Contaminants Detected in Groundwater Above Background Concentrations During the RI (Cont'd)

Analyte	State of Tennessee[1] (mg/L)		Federal (mg/L)				U.S. Army Surgeon General Permissible Drinking Water Criteria (mg/L)	Proposed by the U.S. Army (Etnier, 1987) 10^{-6} risk (mg/L)
	Groundwater Standard	Public Water Supply Standard	MCL	MCLG	Lifetime Health Advisory	SMCL		
Nickel	--	--	0.1 (P,c)	0.1 (P,c)	0.1 (d)	--	--	--
Nitrate	--	10.0	10.0	10.0	--	--	--	--
NB	--	--	--	--	--	--	--	--
RDX	--	--	--	--	0.002 (ab)	--	0.035	--
Silver	0.05	0.05	0.05 (a)	--	0.1 (d)	0.1 (b)	--	--
TETRYL	--	--	--	--	--	--	--	--
Toluene	--	--	1.0 (b)	1.0 (b)	1.0 (d)	0.04 (P,g)	--	--
1,3,5-TNB	--	--	--	--	--	--	--	--
2,4,6-TNT	--	--	--	--	0.002 (ac)	--	0.044	--
Xylenes (total)	--	--	10 (b)	10 (b)	1.0 (d)	0.02 (P,g)	--	--
Zinc	--	5.0	--	--	2.0 (d)	5.0 (f)	--	--

[1] Rules of the Tennessee Department of Health and the Environment, Chapter 1200-5-1-.06, as amended
[2] Lifetime Health Advisory adjusted for 100% relative source contribution from ingestion of drinking water only

- -- Standard not developed for this chemical
- (P) Proposed
- AL Action Level, exceeded if the level of concentration in more than 10% of the targeted tap samples is greater than the specified value (90th percentile)
- (a) 40 CFR, Part 141-National Primary Drinking Water Regulations. 559-563, 620-621.
- (b) Environmental Protection Agency (EPA). 1991. National Primary Drinking Water Regulations; Final Rule. Federal Register. Vol. 56, No. 20, Wednesday, January 30, 1991. 3526-3597
- (c) Environmental Protection Agency (EPA). 1990. National Primary and Secondary Drinking Water Regulations; Synthetic Organic Chemicals and Inorganic Chemicals. Proposed Rule. Federal Register. Vol. 53, No. 143, Wed. July 25, 1990.
- (d) Environmental Protection Agency (EPA). 1991. Health Advisories. Office of Drinking Water. Washington, D.C. November 1991
- (e) Environmental Protection Agency (EPA). 1987. Health Advisories. Office of Drinking Water. Washington, D.C. March 31, 1987.

TABLE 3-2 (Cont'd)
Potential Chemical Specific ARARs and To-Be-Considered Guidance for Contaminants Detected in Groundwater Above Background Concentrations During the RI (Cont'd)

(f) 40 CFR, Part 143-National Secondary Drinking Water Regulations. 674.

(g) Environmental Protection Agency (EPA). 1989. National Primary and Secondary Drinking Water Regulations; Proposed Rule. Federal Register. Vol. 54, No. 97, Monday, May 22, 1989. 22062-22160.

(h) Environmental Protection Agency (EPA). 1985. National Primary Drinking Water Regulations. Synthetic Organic Chemicals, Inorganic Chemicals and Microorganisms. Proposed Rule. Federal Register, Vol. 50, No. 219, Wednesday, November 13, 1985. 46935-47025.

(i) Environmental Protection Agency (EPA). 1991. National Primary Drinking Water Regulations - Monitoring for Synthetic Organic Chemicals; MCLGs and MCLs for Aldicarb, Aldicarb Sulfoxide, Aldicarb Sulfone, Pentachlorophenol, and Barium; Proposed Rule. Federal Register. Vol. 56, No. 20, Wednesday, January 30, 1991. 3600-3614.

(j) The value of 100 μg/liter is for total trihalomethanes (i.e., the sum of chloroform, bromochloromethane, and bromoform).

(k) Environmental Protection Agency (EPA). 198[illegible] Drinking Water Regulations; Maximum Contaminant Level Goals and National Primary Drinking Water Regulations for Lead and Cop[illegible] Proposed Rule. Federal Register. Vol. 53, No. 160, 31515-31578, Thursday, August 18, 1988.

(z) Environmental Protection Agency (EPA). 1988. Health Advisory for Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX). Office of Drinking Water. Washington, D.C. November, 1988.

(ab) Environmental Protection Agency (EPA). 1988. Health Advisory for Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX). Office of Drinking Water. Washington, D.C. November, 1988.

(ac) Environmental Protection Agency (EPA). 1989. Health Advisory for 2,4,6-Trinitrotoluene (TNT). Office of Drinking Water. Washington, D.C. January, 1989.

(am) The MCL for lead is in effect until December 7, 1992, when the Action Level will take its place.

(an) The MCL for barium of 1,000 μg/L shall remain effective until January 1, 1993 when the MCL of 2,000 μg/L will take its place.

TABLE 3-3
Risk-Based Guidance Values for Chemicals at MAAP[1]

Chemical	RfD[2] (mg/kg/day)	CSF[3] $(mg/kg/day)^{-1}$	TBC[4] Guidance (μg/L)
Acetone	0.1	--	3,500
Bis(2-ethylhexyl)phthalate	0.02	--	700
Bis(2-ethylhexyl)phthalate	--	0.014	2.5
1,3-Dinitrobenzene	0.00005	--	1.75
Nitrobenzene	0.0005	--	17.5
Tetryl	NA[5]	--	--
1,3,5-Trinitrobenzene	0.00005	--	2

[1] All values from the Integrated IRIS unless otherwise noted.
[2] RfD = Reference Dose.
[3] CSF = Cancer Slope Factor.
[4] To-Be-Considered guidance.
[5] Not available.

TABLE 3-4
Identification of Potential Chemical-Specific ARARs for Surface Water

Authority	Requirement	Status	Requirement Synopsis
State Regulatory Requirement	Rules of the Tennessee Department of Health and the Environment, Chapter 1200-4-3	Relevant and Appropriate	The State of Tennessee has proposed surface water quality standards and use classifications for surface waters. These proposed standards may also be considered for contaminants in groundwater which discharge to surface water. The proposed standards and use classifications are currently under review by the State Office of the Attorney General.
Federal Criteria, Advisories, and Guidance	Federal Ambient Water Quality Criteria (AWQC)	*To Be Considered*	Federal AWQC are criteria for the protection of aquatic life and human health which have been developed for 95 carcinogens and noncarcinogens.

TABLE 3-5
Potential Chemical-Specific ARARs for Surface Water

Analyte	State of Tennessee[1] (µg/L)			Federal Water Quality Criteria[2] (µg/L)			
	Surface Water Standard for Freshwater Fish and Aquatic Life		Recreation	Freshwater Acute Criteria for Protection of Aquatic Life[(a)]	Freshwater Chronic Criteria for Protection of Aquatic Life[(b)]	Water and Fish Ingestion, Protection of Human Health	Fish Consumption Only, Protection of Human Health
	Criterion Maximum Concentration	Criterion Continuous Concentration					
Acetone	--	--	--	--	--	--	--
Aluminum	--	--	--	--	--	--	--
Arsenic III	360	190	--	360	190	--	--
Arsenic VI	--	--	--	850	48	0.0022	0.0175
Barium	--	--	--	--	--	1,000	--
Cadmium, total recoverable	--	--	--	--	--	--	--
Cadmium, dissolved	1.8⁺	0.66⁺	--	1.8⁺	0.66⁺	10	--
Chloroform	--	--	4,700	28,900	1,240	0.19**	15.7**
Chromium (hexavalent), total recoverable	16	11	--	16	11	50	--
Chromium (trivalent), total recoverable	--	--	670,000*	980⁺	120⁺	170,000	3,433,000
Copper	9.2⁺	6.5⁺	--	9.2⁺	6.5⁺	--	--
Cyanide	22.0	5.2	--	22.0	5.2	--	--
2,4-DNT	--	--	42	--	--	0.11**	9.1**
Ethylbenzene	--	--	29,000	32,000	--	1,400	3,280
Lead, total recoverable	33.8⁺	1.3⁺	--	33.8⁺	1.3⁺	50	--
Manganese	--	--	--	--	--	50	100
Mercury, total recoverable	2.4	0.012	0.15	2.4	0.012	0.144	0.146
Nickel	1,400	160	4,600	790⁺	88⁺	--	--
Nitrate, Nitrite	--	--	--	--	--	--	--
Nitrobenzene	--	--	1,900	27,000	--	19,800	--
RDX	--	--	--	--	300	--	--
Silver	1.2⁺	--	--	1.2⁺	0.12	50	--

TABLE 3-5 (Cont'd)
Potential Chemical Specific ARARs for Surface Water

Analyte	State of Tennessee[1] (µg/L)			Federal Water Quality Criteria[2] (µg/L)			
	Surface Water Standard for Freshwater Fish and Aquatic Life		Recreation	Freshwater Acute Criteria for Protection of Aquatic Life[(a)]	Freshwater Chronic Criteria for Protection of Aquatic Life[(b)]	Water and Fish Ingestion, Protection of Human Health	Fish Consumption Only, Protection of Human Health
	Criterion Maximum Concentration	Criterion Continuous Concentration					
Sodium	--	--	--	--	--	--	--
Tetryl	--	--	--	--	--	--	--
1,3,5-Trinitrobenzene	--	--	--	--	--	--	--
Toluene	--	--	300,000	17,500***	--	14,300**	424,000**
2,4,6-Trinitrotoluene	--	--	--	--	--	--	--
Zinc	65.0+	65.0+	--	65.0+	65.0+	--	--

[1]Source: Rules of the Tennessee Department of Health and Environment, Bureau of Environment, Division of Water Pollution Control, Chapter 1200-4-3, General Water Quality Criteria, January 1991

[2]U.S. EPA, Office of Water Regulations and Standards, Washington, DC, Quality Criteria for Water, 1986, EPA 440/5-86-001

[(a)]1-hour average concentration, not to be exceeded more than once every 3 years on the average.

[(b)]4-day average concentration, not to be exceeded more than once every 3 years on the average.

*10^{-5} risk level is used for all carcinogenic pollutants (organisms only).

**Human health criteria for carcinogens presented for the 10^{-6} risk level.

***Insufficient data to develop criteria. Value is the Lowest Observed Effect Level (LOEL).

--No standard

+Criterion is calculated based on a hardness of 50 mg/L as $CaCO_3$.

following uses: fish, recreation, irrigation, and livestock watering and wildlife. The TDHE classification rule provides that stream segments designated for recreational use will be regulated by numerical toxic limits based on Federal AWQC for the protection of humans from the consumption of contaminated fish alone. The TDHE has established criteria in their water quality standards for cadmium, chromium III and VI, and lead, which may be applicable in setting cleanup standards for treated effluent being discharged to surface waters around MAAP.

Effluent from industrial and sewage treatment plants at MAAP are regulated under the Clean Water Act. The EPA has adopted effluent limitations and guidelines for existing sources and standards of performance for new sources pursuant to Sections 301, 304, and 306 of the Federal Water Pollution Control Act as amended, PL92-500. Table 3-6 shows the available effluent limitations of industrial wastewater treatment plants established under Section 70-330, Tennessee Code Annotated and Rule 12-4-5 (TDHE, 1977) for the chemicals of concern at MAAP. Industrial treatment units, including those at MAAP, are required to achieve at a minimum the concentration provided in Table 3-6 as a maximum effluent limitation when such contaminants are present.

Permits developed under the National Pollution Discharge Elimination System (NPDES) program for discharges to effluent-limited segments contain limitations and standards in accordance with these guidelines. Depending on the conditions of receiving waters and pollutants involved, individually specified effluent limitations may apply. The NPDES permit issued for MAAP includes an effluent limitation for an additional pollutant, defined as total nitrobodies, of 1 mg/L.

3.3 LOCATION-SPECIFIC ARARs

Location-specific ARARs set restrictions on remedial action activities depending on the characteristics of a site or its immediate environs. Much of the information regarding characteristics of MAAP was provided by officials from the State of Tennessee. Table 3-7 lists regulations that may be considered ARARs for MAAP.

3.3.1 Faults

The Earthquake Center recently defined the seismic zone in which MAAP is located. The plant is located in Seismic Zone 2, which is at moderate risk from a large earthquake in the New Madrid Seismic Zone (Stevens, 1989). If any remedial action alternatives requiring site modification are selected, the RCRA regulation governing placement of hazardous wastes in fault zones may be relevant and appropriate requirements.

3.3.2 Wilderness Areas, Wildlife Refuges, and Scenic Rivers

There are no wilderness areas, wildlife refuges, or wild or scenic rivers inside of the plant boundaries (Hurst, 1989).

3.3.3 Wetlands and Floodplains

The Flood Hazard Boundary Map and Flood Insurance Rate Maps, maintained by the Federal Emergency Management Agency (FEMA), indicate that there are some areas of MAAP that are located within the approximate 100-year floodplain (FEMA 1988a; FEMA 1988b). The Flood Plain Information Report (USACE, 1974) also identifies some additional areas at MAAP that are subject to flooding during a 100-year flood (ORNL, 1990). Therefore, the regulation prohibiting site modifications in a 100-year floodplain may be an ARAR for MAAP.

TABLE 3-6
Tennessee Effluent Limitations for Industrial Wastewater Treatment Plants[1]

Analyte	Daily Maximum Concentration (mg/L)
Aluminum	250
Arsenic	1.0
Barium	5.0
Cobalt	10.0
Copper	1.0
Cyanide	0.05
Iron (total)	10.0
Manganese	10.0
Silver	0.05
Zinc	2.0
Cadmium	0.01
Chromium (total)	3.0
Lead	0.1
Mercury	0.05

[1] Source: TDHE, 1977

TABLE 3-7
Selected Location-Specific ARARs

Location	Requirement	Prerequisite(s)	Citation
Within 61 meters (200 feet) of a fault displaced in Holocene time	Prohibits new treatment, storage or disposal of hazardous waste	RCRA hazardous waste; treatment, storage, or disposal	EPA Regulations for Owners and Operators of Permitted Hazardous Waste Facilities, 40 CFR 264.18
Within 100-year floodplain	Facility must be designed, constructed, operated, and maintained to avoid washout by a 100-year floodplain	RCRA hazardous waste; treatment, storage, or disposal	EPA Regulations for Owners and Operators of Permitted Hazardous Waste Facilities, 40 CFR 264.18
Within floodplain	Must take action to avoid adverse effects, minimize floodplain destruction, restore and preserve natural and beneficial values, and minimize impact of floods on human safety, health, and welfare	Action of Federal agencies pertaining to: acquiring, managing, and disposing of lands and facilities; construction or improvements; and conducting activities and programs affecting land use in *flood-prone areas*	Executive Order 11988; Floodplain Management (40 CFR 6, Appendix A)
Wetland	Action to avoid adverse impact, minimize potential harm, and to preserve and enhance wetlands to the extent possible	Wetland as defined 40 CFR 6, Appendix A Section 4; Action by Federal agencies involving construction of facilities or management of property in wetland areas	Executive Order 11990; Protection of Wetlands (40 CFR 6, Appendix A)
Within area where action may cause irreparable harm, loss, or destruction of significant artifacts	Must take action to recover and preserve artifacts	Alteration of terrain that threatens significant scientific, prehistorical, historical, or archaeological data	National Archaeological and Historic Preservation Act (16 USC 469); National Historic Landmarks Program (36 CFR 65)

TABLE 3-7 (Cont'd)
Selected Location-Specific ARARs

Location	Requirement	Prerequisite(s)	Citation
Within 61 meters (200 feet) of a fault displaced in Holocene time	Prohibits new treatment, storage or disposal of hazardous waste	RCRA hazardous waste; treatment, storage, or disposal	EPA Regulations for Owners and Operators of Permitted Hazardous Waste Facilities, 40 CFR 264.18
Historic project owned or controlled by Federal agency	Must take action to preserve historic properties; planning of action to minimize harm to National Historic Landmarks	Federal agencies must get approval for actions that affect property included in, or eligible for the National Register of Historic Places	National Historic Preservation Act Section 106 (16 USC 470 et seq.); 36 CFR 800.1 National Historic Landmarks Program (35 CFR 65)
Critical habitat upon which endangered or threatened species depends	Action to conserve endangered or threatened species; must not destroy or adversely modify critical habitat; consultation with Department of Interior	Determination of presence of endangered or threatened species	Endangered Species Act of 1973 (16 USC 1531 et seq.); 50 CFR 402
Within area affecting stream or river	Must take action to protect affected fish or wildlife resources; prohibits diversion, channeling, or other activity that modifies a stream or river and affects fish or wildlife	Presence of fish and wildlife resources	Fish and Wildlife Coordination Act (16 USC 661 et seq.)

Three major watersheds (the Middle Fork of the Forked Deer River, Wolf Creek, and Rutherford Fork of the Obion River) and one minor watershed (Hall Branch of Johns Creek) drain MAAP (Blaylock,1978; USATHAMA, 1988). Areas at MAAP subject to flooding after heavy rains, generally four inches or more in twelve hours or less, include portions of Hall's Branch and Wolf Creek (Blaylock, 1978; USACE, 1978).

Wetlands occur throughout the site (Powers, 1989). The State of Tennessee State Conservation Department classifies wetlands as areas having hydric soils and woody vegetation, therefore meeting the requirements defining a wetland according to the U.S. Department of Agriculture (Ellis, 1991). If any remedial actions are contemplated that would impact wetland areas, the regulations found in Executive Order 11988 and Executive Order 11990 may be ARARs.

3.3.4 Historic Sites and Archaeological Findings

There are three known archaeological sites at MAAP located on high ground overlooking Wolf Creek (Blaylock, 1978). One site is located in a cultivated area. Materials consist mostly of middle Archaic artifacts. The sites have not been extensively examined and therefore, their exact importance is unknown (Blaylock, 1978). An archaeological overview and management plan has been developed for MAAP; however, it does not provide conclusive information and a complete archaeological investigation needs to be conducted (Smith, 1989).

There is one historical structure of significance on MAAP, the Browning House, childhood home of Gordon Browning who was governor of Tennessee in 1937-38 and 1942-52 (MacDonald and Mack Partnership, 1984). The building is located adjacent to Line Z in the northwest portion of the installation. The Browning House has been entered into the National Register of Historic Places as provided for in the Preservation Act of 1966 (MacDonald and Mack Partnership, 1984). If any remedial actions are considered that would impact the archaeological sites or the historic home, the regulations listed in Table 3-7 may be an ARAR.

3.3.5 Rare, Threatened or Endangered Species

Rare or endangered species of animals have not actually been observed at MAAP; however, a 1978 report prepared by the Department of the Army recommends that four species of birds should be actively investigated to establish their status at the site. These species include: Sharp-shinned Hawk (Accipiter striatus velox), Cooper's Hawk (Accipiter cooperi Bonaparte), BeWick's Wren (Thryomanes bewickii), and the Grasshopper Sparrow (Ammodramus savannarum pratensis). These species appear on the State and Federal endangered list and the National Audubon Society's Blue List. Several endangered, threatened, rare, and special concern species occur in Gibson and Carroll County, Tennessee; however, further site study is needed to determine their status at MAAP and in the surrounding areas (Tennessee Department of Conservation, 1989a; Pitts, 1989).

One State-listed threatened plant, the Compass Plant (Silphium laciniatum), has been observed near the roadside by the boundary fence, on the southeast corner of MAAP (Eagar, 1989; Tennessee Department of Conservation 1989b). The Compass Plant has also been observed on the extreme southern edge of MAAP within a few hundred feet of the boundary fence (Blaylock, 1978).

If remedial action alternatives requiring site modifications are selected, regulations found in the Endangered Species Act of 1973 may be relevant and appropriate. In addition, any regulation cited in the Tennessee Nongame and Endangered or Threatened Wildlife Species Conservation Act (in Tennessee Code Annotated Section 70.8101) may be relevant and appropriate.

3.3.6 Air Quality

The ambient air quality at MAAP is considered good according to the most recent documentation of air monitoring conducted at MAAP (Blaylock, 1978). Air quality monitoring stations were constructed at MAAP but were later dismantled. The State of Tennessee does not specify that ambient air monitoring is required for the site. The Tennessee Air Pollution Control Regulations, Chapter 1200-3-8, provide guidelines for the generation and control of fugitive dust. According to the established guidelines, the emission of fugitive dust is not permitted to exceed five minutes per hour or twenty minutes per day as to produce a visible emission beyond the property line on which the emission originates. Based on past disposal practices conducted in the burning grounds, Tennessee Air Pollution Control regulations concerning fugitive dust may be an ARAR for the site.

3.4 ACTION-SPECIFIC ARARs

Based on the remedial alternatives for groundwater treatment developed in Section 5.0, certain action-specific ARARs may be applicable, depending on the actual alternative selected. The following paragraphs provide information concerning these action-specific ARARs.

If the existing ditches on site are determined to be wet weather conveyances, discharge to these ditches would be regulated by groundwater criteria rather than surface water quality criteria (both described above). Surface water criteria would only be enforced if and when this discharge reached the Rutherford Fork, over one mile away. If the discharge into the ditch reaches the Rutherford Fork, a "Mixing Zone", as defined in Chapter 1200-4-3-.04 of the Tennessee State Water Laws, will be established at the discharge point. This zone is restricted in size and must not disturb the conditions of fish or other aquatic communities, or endanger public health or welfare.

According to Rule 1200-4-6-.14 of the State of Tennessee Water Laws, re-injection of treated groundwater is permissible. A Class V injection well may be used provided that no hazard to existing or future use of the groundwater as cited in rule 1200-4-6-.05 exists. Groundwater usage under this later rule includes domestic water supply, industrial water supply, livestock watering and wildlife, surface water drainage, and irrigation. The rule stipulates that groundwater used for these purposes may be subject to treatment prior to the actual use. Treatment of extracted groundwater will take place prior to use of a Class V injection well for re-injection, and therefore will not disqualify the groundwater from being used for any of the stated uses in the rule.

Since land re-surfacing and construction activities will be performed upon implementation of a treatment alternative, air quality ARARs are applicable. For each technology identified, applicable air quality regulations will be identified and considered. A technology suitable for treatment of organics is ultraviolet (UV)-oxidation. This process may require the generation of ozone, a regulated substance, for use as an oxidant. The Tennessee Ambient Air Quality Primary Standard for ozone is 0.12 mg/L by volume (Rule 1200-3-3-.03). This standard will be applicable if this process is implemented. Noise restrictions during construction work should also be implemented.

An important potential ARAR are the Land Disposal Restrictions (LDRs) implemented by EPA under the Hazardous and Solid Waste Amendments (HSWA). Under these restrictions, hazardous waste may not be landfilled without meeting the prescribed treatment standard. These LDRs may also apply to groundwater treatment sludges and spent carbon from groundwater treatment.

Additionally, all applicable requirements under RCRA and NEPA are ARARs.

4.0 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES

Potential remedial technology types and associated process options within each of the general response categories are identified and evaluated in this section. General response actions are broad remedial approaches capable of meeting remedial action objectives. Technology types are general categories which fall within a general response action. Process options are specific processes within each technology. Figure 4-1 provides the relationship between the general response actions, technology types, and process options which are considered for groundwater action at this site. Applicability to specific chemical contaminants and MAAP O-Line Pond characteristics, as well as ability to satisfy remedial action objectives are considered in identifying the technology types and associated process options.

4.1 IDENTIFICATION OF GENERAL RESPONSE ACTIONS

General response actions described herein are broad remedial approaches capable of meeting the remedial action objectives for the site. Although an individual response action may be capable of satisfying the remedial action objectives alone, combinations of response actions are usually required to adequately address site problems. General response actions were selected for the MAAP O-Line Ponds Area in accordance with methods presented in EPA's Interim Final Edition of "Guidance for Conducting RI/FS Under CERCLA," October 1988.

General response actions applicable to this site are the following:

No Action - The NCP and CERCLA as amended require the evaluation of a No Action alternative as a baseline for comparison with other remedial alternatives. The No Action alternative does not involve any concrete remedial action; therefore, environmental media at the site, or emanating from the site, remain contaminated. For this reason, CERCLA as amended requires a review of site conditions every five years.

Limited Action - Limited Action technologies do not reduce the toxicity, mobility, or volume of contamination but are implemented to reduce the probability of physical contact with contaminated media. Limited Action technologies consist of long-term monitoring activities, physical barriers, and administrative actions such as installation security, which reduce the potential for exposure of populations to contaminated media. Limited Action technologies are used to inform the public, provide a data base, and evaluate changes in site conditions over time.

Collection - Collection technologies involve the removal of contaminated groundwater from the aquifer. These technologies do not provide treatment of contaminated groundwater but may be used to reduce the volume of contaminated groundwater within the aquifer and, in conjunction with treatment and/or disposal responses, may reduce the toxicity and mobility of contaminants. Pumping (or passive groundwater removal technologies such as barrier drains) can also be used to control groundwater levels and site hydrologic characteristics. Additionally, the pumping of groundwater extraction wells produces a cone of depression around the wells. This reverses the local hydraulic gradient on the downgradient side and the mobility of contaminants in the groundwater near the extraction wells is, therefore, reduced.

On-Site Groundwater Treatment - Treatment technologies reduce the toxicity and volume of contaminants in groundwater through physical, biological, chemical, or thermal processes. Treatment to reduce toxicity includes methods which destroy or modify chemical properties to render the compounds less harmful. Treatment residuals (such as sludge) and the treated effluent will then be disposed either on or off site.

MEDIUM	GENERAL RESPONSE ACTIONS	TECHNOLOGY TYPES	PROCESS OPTIONS
GROUND WATER	NO ACTION	NONE	NOT APPLICABLE
	LIMITED ACTION	LONG-TERM MONITORING	GROUNDWATER MONITORING
			SURFACE WATER MONITORING
		ADMINISTRATIVE ACTIONS	INSTITUTIONAL RESTRICTIONS
			ACCESS RESTRICTIONS
			PUBLIC EDUCATION
			EMERGENCY PROVISIONS
	COLLECTION	EXTRACTION	EXTRACTION WELLS
	ON-SITE TREATMENT	PHYSICAL TREATMENT	CARBON ADSORPTION
			ION EXCHANGE
			GRANULAR MEDIA FILTRATION
		CHEMICAL TREATMENT	ULTRAVIOLET-OXIDATION
			PRECIPITATION

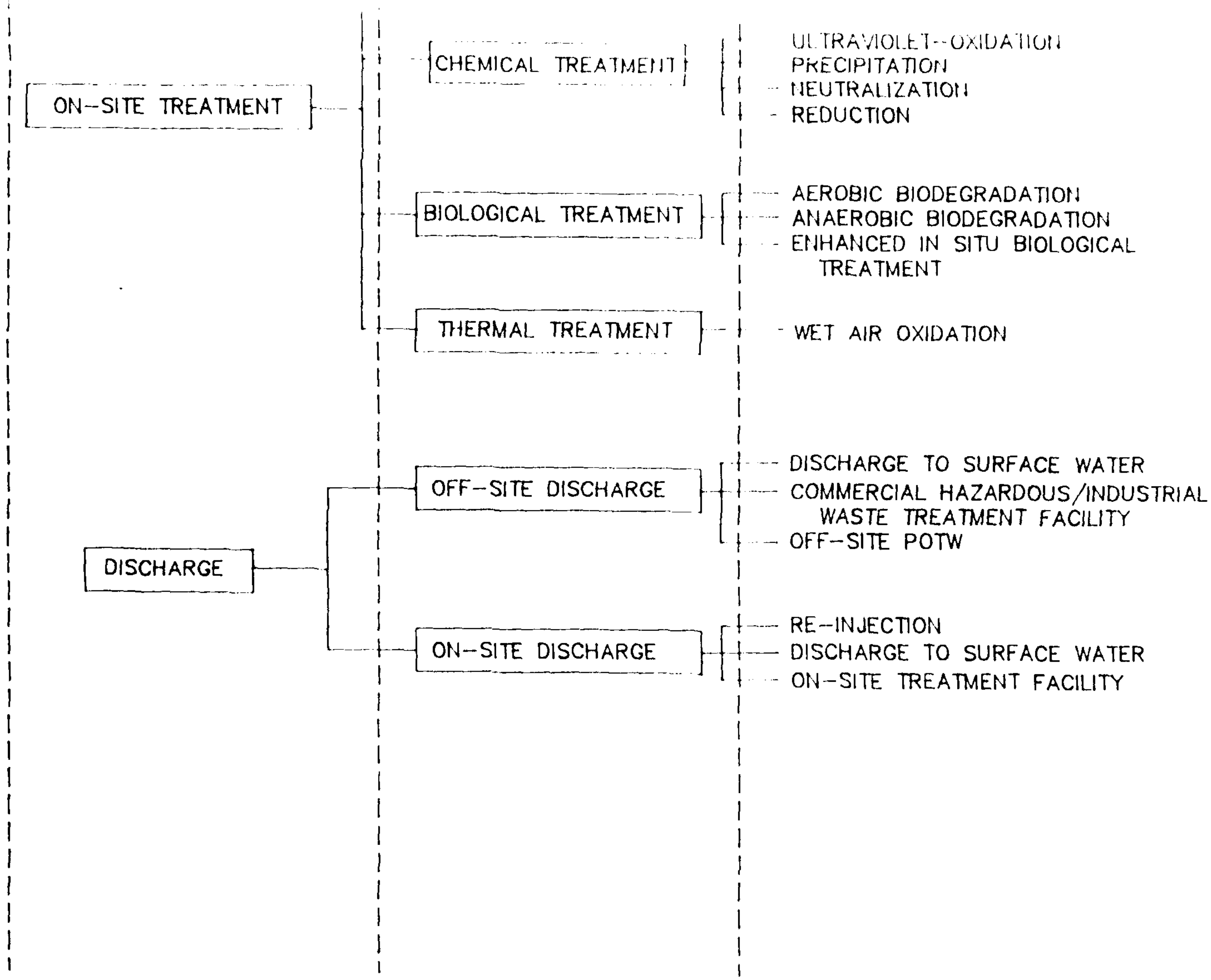

FIGURE 4-1
MILAN ARMY AMMUNITION PLANT
REMEDIAL TECHNOLOGIES FOR GROUNDWATER

Compiled by: ICF KAISER ENGINEERS
Drawn by: K. CHMETE | Project Code: 04302
Checked by: J. McKENDRY | Dwg no.: 09229102
Date: 03-30-92

2

Discharge of Groundwater - Discharge technologies involve the disposal of treated groundwater into an on-site or off-site POTW, discharge into an on-site or off-site surface water body, or re-injection into the aquifer. The discharge of treated materials must satisfy all effluent limitations.

4.2 IDENTIFICATION AND SCREENING OF TECHNOLOGY TYPES AND PROCESS OPTIONS

Process options within potential remedial technology types are evaluated based on three criteria: implementability, effectiveness, and cost. The following factors will be considered under the implementability criterion:

- Site characteristics may limit the construction or effective functioning of the technology. Contaminants have been detected above health advisories at depths up to 170 feet below the surface. The large volume of groundwater which may require remediation (estimated to be as much as 1×10^9 gallons[1]), dictates the need for a large flow rate. This is considered when screening treatment technologies.

- Waste characteristics may limit the use or effective functioning of the equipment. The effectiveness of groundwater treatment technologies may be limited by the concentrations of contaminants and the mixture of inorganic constituents, and semivolatile organics.

- The equipment needed to implement the technology may not be available or the capacity of off-site or on-site treatment or disposal facilities may not be sufficient to implement the technology.

- The need to obtain permits for off-site transport, disposal, or construction will be considered.

The following factors will be considered under the effectiveness criterion:

- The reliability in meeting chemical-specific ARARs or human health-based risk levels are considered. Those process options which cannot achieve the remedial action objectives are eliminated.

- The degree of permanent reduction in toxicity, mobility, or volume of the waste are considered. As required by CERCLA, process options which achieve reduction in these characteristics are given preference.

- The long-term risks due to treatment residuals or containment systems are considered.

- The risks to the public, workers, or the environment during construction and implementation of the process option are considered.

Cost is given limited consideration in the screening to compare process options within a technology type. The relative magnitude of capital and operation and maintenance (O&M) costs are considered. Many technology types can be implemented with a number of process options. If process options are sufficiently similar that the selection of one will not limit the evaluation of the technology type, then one representative process option is selected and evaluated. If, however, the performance, cost, or implementation of process options is sufficiently different, then more than one process option is selected.

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[1]This value is based on plume dimensions of 1,500 feet wide, 3,600 feet long, and 125 feet thick. Soil porosity is assumed to be 20%.

Technology types and process options which have potential applicability in light of this screening are assembled and evaluated in detail in Sections 5.0 and 6.0.

4.2.1 No Action

Description - No Action is not a category of technologies but provides a risk baseline to which all other alternatives may be compared. This response does not involve remedial activity, monitoring, or restrictions.

Initial Screening - No Action does not reduce the toxicity, mobility, or volume of contamination. However, as required by the NCP and CERCLA as amended, the No Action alternative is retained for consideration in alternatives assembly.

4.2.2 Limited Action

Limited action process options include groundwater monitoring, surface water monitoring, institutional restrictions, access restrictions, public education, and emergency provisions. These are described and initially screened below.

4.2.2.1 Groundwater Monitoring. Description - Groundwater monitoring at the northern boundary of the cap and along the downgradient path of the plume allows effective contamination tracking. If no groundwater remediation is implemented, groundwater monitoring at hazardous waste sites is usually conducted to determine whether contaminant concentrations have decreased to safe levels through natural flushing and/or the attenuation of contaminants in the groundwater system.

Initial Screening - Groundwater monitoring is required as long as contaminated groundwater remains at the site. Groundwater monitoring is retained for consideration in alternatives assembly.

4.2.2.2 Surface Water Monitoring. Description - Conducting surface water monitoring in the Rutherford Fork of the Obion River and in intermittent streams located in surrounding ditches will indicate if contamination has migrated into the surface water through groundwater transport. In addition, conducting surface water monitoring for some time after remedial actions have been implemented can help to determine whether complete capture of the contaminant plume was achieved.

Initial Screening - Analysis of the groundwater potential data indicates that some fraction of the groundwater probably discharges to the Rutherford Fork. Even though this recharge may be minimal since the majority of contaminants in the groundwater move downward through the aquifer rather than discharging into the Rutherford Fork, it is important to monitor the surface water for the contaminants of concern. Future surface water monitoring may be used in conjunction with groundwater monitoring to determine whether remedial actions were successful in capturing the full contaminant plumes. Surface water monitoring is retained for consideration in the alternatives assembly.

4.2.2.3 Institutional Restrictions. Description - Institutional restrictions involve controlling access to contaminated areas by implementing administrative policies. Administrative policies of interest include restricting future property uses within contaminated areas and restricting the drilling of new drinking water wells.

Initial Screening - Although no evidence was found that contamination emanating from the O-Line Ponds unit via groundwater or surface water is resulting in direct and immediate human health impacts, the current or future releases from this area have been found to pose a future threat. In addition, institutional restrictions could be used to prevent disturbance of the O-Line Ponds cap. Institutional

restrictions will help to reduce the potential for future exposure, and are retained for consideration in alternatives assembly.

4.2.2.4 Access Restrictions. Description - Access restrictions involve controlling access to contaminated areas by installing physical boundaries and/or signs.

Initial Screening - The O-Line Ponds are currently capped and fenced on all sides; therefore, access restrictions have already been imposed on the source. Access restrictions greatly reduce the potential for exposure without excessive costs. Access restrictions are retained for consideration in alternatives assembly.

4.2.2.5 Public Education. Description - An increased public awareness of the hazards present at the site would be achieved through public meetings, presentations at local schools, press releases, and posting of signs.

Initial Screening - Public education will facilitate site remediation by keeping potentially affected individuals aware of events at the site. Public education is retained for consideration in alternatives assembly.

4.2.2.6 Emergency Provisions. Description - In the event of an unexpected deterioration of site conditions resulting in an increased threat to public health and the environment, emergency measures are outlined to allow prompt attention to the problem. Existing emergency provisions, if any, should be identified and updated.

Initial Screening - Outlining emergency measures allows for prompt and organized response to threats to public health and the environment. Emergency provisions are retained for consideration in alternatives assembly.

4.2.3 Collection of Groundwater

Extraction wells and subsurface drains are two process options considered for the collection of contaminated groundwater at the O-Line Ponds area. These processes may also be implemented to control groundwater elevation and flow, and contaminant migration from the site. Collection methods control contaminant mobility but do not directly reduce the toxicity or volume of waste.

4.2.3.1 Extraction Wells. Description - Extraction well systems consist of a series of pumping wells installed into strata to remove groundwater. These systems are most useful in formations with high transmissivity. Extraction wells do not directly reduce the toxicity of the extracted contaminated groundwater but are used in combination with treatment or disposal technologies. These wells can also be used for gradient control to reduce the rate of contaminant migration. Alternatively, a pumping scheme of varying flow rates can be used to optimize groundwater removal from a specific zone of contamination. Extraction wells represent a well developed and highly reliable technology that has been used at many hazardous waste sites. This technology uses simple and readily available equipment, but its application requires long-term operations at the site.

Initial Screening - Extraction wells can be used to pump contaminated groundwater directly to on-site treatment. Extraction wells have been considered versatile and technically proven for contaminated groundwater remediation. They provide many possible configurations and operational strategies. A potential disadvantage is operational complexity and the need to discharge treated groundwater. Extraction well technology is retained for consideration in alternatives assembly.

4.2.3.2 Subsurface Drains. Description - A basic subsurface drain, or extraction trench, is an unlined trench backfilled with a highly permeable material, such as gravel, and is drained by a perforated pipe placed at the base of the gravel bed. An extraction trench collects water from both upgradient and downgradient directions. As the water enters the perforated pipe, it flows to a central collection point where a pump is used to remove the water for treatment and/or disposal.

Subsurface drain technologies are most useful in formations with low hydraulic conductivities and when the flow of groundwater must be controlled over large areas. Subsurface drains may be utilized to extract contaminated groundwater or as a technique to control groundwater elevations and flows. Construction of the subsurface drain would be similar for both goals; however, the optimum placement of the drain would vary with the objective.

Initial Screening - A subsurface drainage system is an effective method of collecting groundwater in a low permeability soil environment. Because relatively large recharge rates have been observed in the wells in the O-Line Ponds area, subsurface drains most likely are not necessary. Since the contaminants have been detected very deep within the aquifer, the installation of subsurface drains would also be rather costly and difficult to implement. Extraction wells are a more effective method of collecting groundwater. For this reason, subsurface drains are eliminated from further consideration.

4.2.4 On-Site Groundwater Treatment

On-site treatment technologies are evaluated based on application to waste streams containing both organic (e.g., explosives) and dissolved metal contaminants. On-site groundwater treatment can be accomplished by implementing mobile treatment units on a temporary basis, or by constructing an on-site semi-permanent treatment system. The available technologies for on-site groundwater treatment are physical, chemical, biological, and thermal processes as follows:

Physical Treatment - Physical treatment involves separating chemicals from water such that the water may then be discharged or treated further by other methods. Physical processes which may be applicable to the O-Line Ponds area are carbon adsorption, air and steam stripping, ion exchange, granular media filtration, flocculation/sedimentation, and reverse osmosis.

Chemical Treatment - Chemical treatment involves modifying contaminants through chemical reactions such that they are no longer hazardous. It may also be used to make contaminants more treatable by subsequent processes. Chemical treatment processes of interest are ultraviolet-oxidation, precipitation, neutralization, and reduction.

Biological Treatment - Biological treatment uses microorganisms to degrade organic contaminants. Both aerobic (in the presence of oxygen) and anaerobic (in the absence of oxygen) processes are available. Aerobic process options under consideration are activated sludge, trickling filters, rotating biological contactors, and powdered activated carbon treatment (PACT). The most common anaerobic process is anaerobic biological degradation. Enhanced in-situ biological treatment is an additional process option.

Thermal Treatment - Thermal treatment involves using elevated temperatures to modify or destroy contaminants. Wet air oxidation is the only thermal treatment process option under consideration.

The following is a description and initial screening of each of the process options listed above.

4.2.4.1 Carbon Adsorption. Description - Carbon adsorption removes organics from aqueous solutions through surface attachment between the solute and the internal pore structure of the granular activated carbon (GAC). This technology can treat waste streams containing organic compounds with

high molecular weights, high boiling points, and low solubilities and polarities. Water containing total dissolved organic concentrations up to 10,000 mg/L can be successfully treated. Pretreatment is often necessary for optimum performance as suspended solids should be less than 100 mg/L, and dissolved inorganics, oil, and grease should be less than 10 mg/L (USEPA, 1985).

A modified GAC system using treated GAC and pH optimization has been proven effective in removing heavy metals from aqueous streams to levels in field trials elsewhere. Recent proprietary information has indicated that levels may be reduced to near, if not below, AWQC by optimizing the pH of the water and adding reagents to cause the carbon unit to treat inorganics in a way similar to an ion exchange system. In the study, cadmium levels were lowered to between 0 and 5 μg/L, and chromium (VI) levels were lowered to between 0 and 40 μg/L. One disadvantage of using carbon to remove heavy metals is the difficulty in reactivation or regeneration of carbon contaminated with these constituents. Although it can be achieved using electrolytic processes, this method is costly. Treatability studies would be necessary to ensure the adequate removal of these heavy metals and develop design parameters.

Initial Screening - Carbon adsorption is a proven technology which is readily implemented and reliable for treating aqueous waste streams contaminated with dissolved organics. This technology can remove dissolved organics, including explosives, to levels below 1 μg/L (USATHAMA, 1990a). GAC is currently used at MAAP to remove explosives from process waters at the pink water treatment facilities (PWTF). Although the current process is designed to achieve an NPDES limit for total explosives of 1,000 μg/L at MAAP, GAC has been used at other sites to achieve far lower effluent levels. Calgon Carbon Corporation has treated influent streams at the Ravenna Army Ammunition Plant which exceeded 100 mg/L of 2,4,6-TNT. Levels were reduced below the NPDES permit limit of 0.14 mg/L using GAC (Chemical Processing, 1983). Calgon representatives report that levels can be reduced to low-μg/L levels with the proper design. Previous pilot tests at MAAP indicate that explosives detected in the groundwater may be removed concurrently using continuous flow GAC. Levels of less than 1 μg/L were achieved for 2,4,6-TNT and RDX. Influent levels used during this test, however, were less than those detected during the RI of the O-Line Ponds area (USATHAMA, 1990). Although carbon adsorption has been found to be successful in treating explosive-contaminated groundwater, treatability studies are necessary to determine if desired effluent concentrations are achievable in a cost-effective manner given the high flow rate. Pretreatment may be necessary to remove suspended solids or inorganics which may foul the system. Carbon adsorption used for the removal of organics is retained for consideration in alternatives assembly. A concept diagram of this process is provided in Figure 4-2.

Spent carbon can be disposed or recycled through several methods. Landfilling, regeneration, and reactivation are three common methods. Landfilling would involve periodic testing of the carbon to determine if it is a hazardous waste under RCRA. If the carbon is determined to be a non-hazardous waste, then disposal in a Subtitle D landfill could occur. However, if the spent carbon is a hazardous waste, then a suitable Subtitle C facility must be found and the associated costs of storage, transport, and disposal are much higher. In addition, the Army would be held responsible for the proper handling and disposal of the carbon; if disposal facility mismanagement occurs and the disposal site falls under a CERCLA action, then the potential liability associated with the carbon could be very large.

Carbon regeneration uses high temperature steam to volatilize contaminants on the spent carbon rendering it suitable for further use. This process is not feasible for carbon contaminated with explosives because explosives are not sufficiently volatile to allow removal through this process. In addition, the process requires treatment of the steam and water used to remove the contaminants.

Carbon reactivation uses thermal processes (typically rotary kiln incineration) to remove contaminants and often provides a more efficient means of disposal.. Spent carbon used for removing explosives from water has been reactivated at MAAP as well as at other facilities where concentrations of nitrobodies have ranged from 5 mg/L to 30 mg/L. These levels are similar to the concentrations

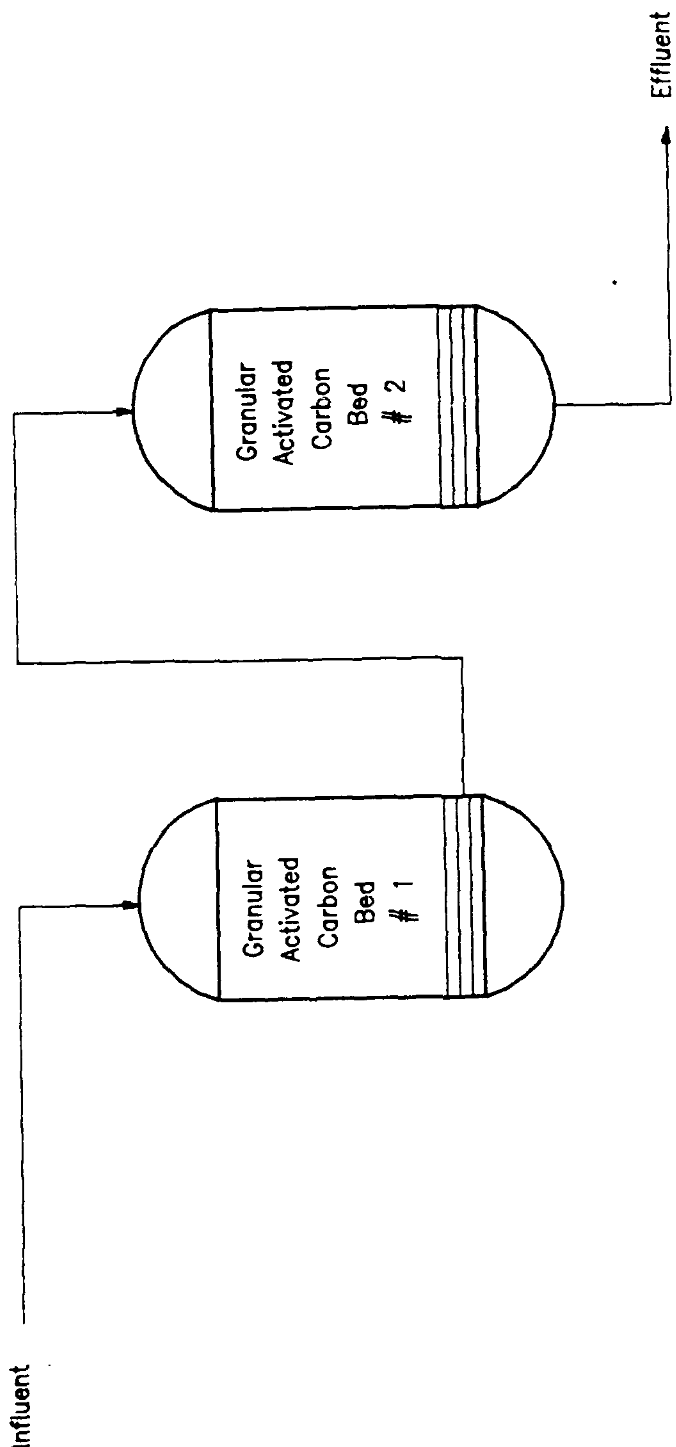

FIGURE 4-2
MILAN ARMY AMMUNITION PLANT
CARBON ADSORPTION PROCESS DIAGRAM
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Project Code 04302
Dwg No. 09229114

expected at the O-Line Ponds area. However, the amount of carbon returned after reactivation and the decreased efficiency of this reactivated carbon make this option infeasible. Only 20% to 60% of the spent carbon from these sites has been retrieved from reactivation processes. It may be necessary to purchase over 50% virgin carbon to make up for lost carbon. Although this appears to be a significant cost savings over purchasing 100% virgin carbon after breakthrough, experience has shown that the reactivated carbon which is retrieved has been 20% to 80% less efficient in removing explosives from water (personal communication with Wayne Sisk, USATHAMA, May 1992). Due to the nature of the contaminants, explosives held at the carbon activation sites implode during the rotary kiln incineration process. Such implosions destroy activation sites, which decreases the removal efficiency of the carbon (personal communication with Tim Sokol, Envirotrol, May, 1992). The success rate of reactivating spent carbon used to treat water contaminated with explosives is low and is not recommended at the O-Line Ponds area. One method of spent carbon disposal which is currently being used by MAAP is through Solvent Recovery, Inc. This company uses the spent carbon as an additive to raise the Btu content of the fuel used for their cement manufacturing process. This process currently serves as an economical method of proper spent carbon disposal.

Carbon adsorption will not be considered further for the removal of metals. The process in effect operates as an ion exchange system. Since ion exchange, screened below, is a more established and well known technology for the removal of heavy metals, it will be considered in place of this technology.

4.2.4.2 Air and Steam Stripping. Description - Air stripping is a mass transfer operation in which volatile contaminants in water are transferred to the gaseous phase. This process works best on contaminants with high volatility and low solubility. Vapor phase carbon adsorption beds are often used for control of atmospheric discharge of exhaust gases. Steam stripping differs from air stripping in that it uses heat to enhance the air stripping process for low to moderately volatile, water soluble compounds. Both air and steam stripping can be used to treat chlorinated hydrocarbons, aromatics, and other organics with limited solubility and moderate vapor pressures.

Initial Screening - Air stripping can remove most organics with Henry's Law Constants greater than 3×10^{-3} atm-m/mole (USEPA, 1985). However, the explosive compounds detected in the groundwater at the O-Line Ponds area have Henry's Law constants less than this value and will not be removed by either air or steam stripping. For this reason, this alternative has been eliminated from further consideration.

4.2.4.3 Ion Exchange. Description - Ion exchange is a process in which ions in an aqueous phase are displaced by free ions of the same charge contained in a solid phase medium called a resin. Synthetic resins are charged with the free ions and, after exchange, can be regenerated easily. The resins are stable, highly tolerant of temperature and pH changes, and can be tailored to address specifications.

Specific ion exchange systems must be designed on a case-by-case basis. It is inherently difficult to design and operate an ion exchange system for a complex inorganic and organic waste stream. Several ion exchange columns in series, including both cation and anion exchanges, may be required to remove the various inorganic ions present at the site. A pilot study is required to determine the overall effectiveness of ion exchange and the effect and compatibility of the wide range of inorganic and organic chemicals on the system.

This technology has been shown to effectively remove metals down to the low-μg/L level. This system can be selective in its removal of heavy metals through proper selection of the ion exchange resins. The system is prone to clogging and should follow an organics removal system and a precipitation unit. In addition, water to be treated should be free of oxidants since their presence affects the ability of

the resins to exchange ions. If this system is used after a UV-oxidation system, this factor may be of concern (Corbitt, 1990).

Initial Screening - Ion exchange systems are designed primarily for removal of inorganics and are reliably effective for this purpose. Sorptive resins may be used to remove polar and non-polar organics; however, their use is relatively new and their reliability is not well known. Without reliable data on the effectiveness of sorptive resins on treating explosive-contaminated groundwater, the use of this process may be limited. In addition, regeneration chemicals may be difficult to select. Ion exchange columns are prone to clogging from a high concentration of total suspended solids (TSS). TSS values should fall below 50 mg/L, and waste streams should be free of oxidants. This technology may be considered as a finishing step in removing heavy metals such as cadmium after the organics treatment assuming the TSS is within the permissible range. This technology will be retained for consideration in alternatives assembly. A concept diagram of this process is shown in Figure 4-3.

4.2.4.4 Granular Media Filtration. Description - Granular media filtration (GMF) involves passing fluids through a bed of granular material which collects suspended solids. Filter beds are normally constructed of sand or sand with anthracite coal. The filter media is periodically regenerated by backflushing; however, backflushed material requires recycling or collection and disposal. Filter media loses effectiveness after extended usage and also requires disposal.

Initial Screening - GMF is routinely used and easily implemented. It is often an interim step between two other treatment processes. GMF can remove suspended metal precipitate particles following precipitation and before carbon adsorption. This process requires a relatively low level of suspended solids in the influent in order to achieve effective removal of suspended solids. Visual inspections of the groundwater collected during the RI near the O-Line Ponds (and comparisons of filtered metals levels to unfiltered metals levels) indicates that this pretreatment option could effectively remove suspended solids prior to further treatment. Filtration could also be used as an intermediate step between processes. GMF is retained for consideration in alternatives assembly. A concept diagram of this process is given in Figure 4-4.

4.2.4.5 Flocculation/Sedimentation. Description - Flocculation/sedimentation is used for clarification of wastewater containing suspended solids. Flocculation is the time dependent physical process consisting of the aggregation of solids into particles large enough to be separated by sedimentation. Flocculation involves the addition of a coagulating agent to initiate particle agglomeration. Flocculation/sedimentation is a well developed commercial process.

Initial Screening - Flocculation/sedimentation is easily implemented and routinely used as an interim step between other treatment processes where solids may interfere with equipment operation. Flocculation/sedimentation is incorporated into the precipitation process which is screened below. Because heavy metals removal may be a necessary step in the remedial action taken, this process option will be considered as a part of precipitation rather than by itself. Therefore, this process option alone is eliminated from further consideration.

4.2.4.6 Reverse Osmosis. Description - Osmosis occurs when two solutions of different concentrations reach equilibrium across a semi-permeable membrane. The solvent (water in this case) naturally flows from the less concentrated solution to the more concentrated solution. Reverse osmosis involves reversing this process by pressurizing the solution with the higher concentration above the osmotic pressure. The water flows out of the more concentrated solution leaving the contaminants as residue on the other side of the membrane. The reverse osmosis process is reported to remove between

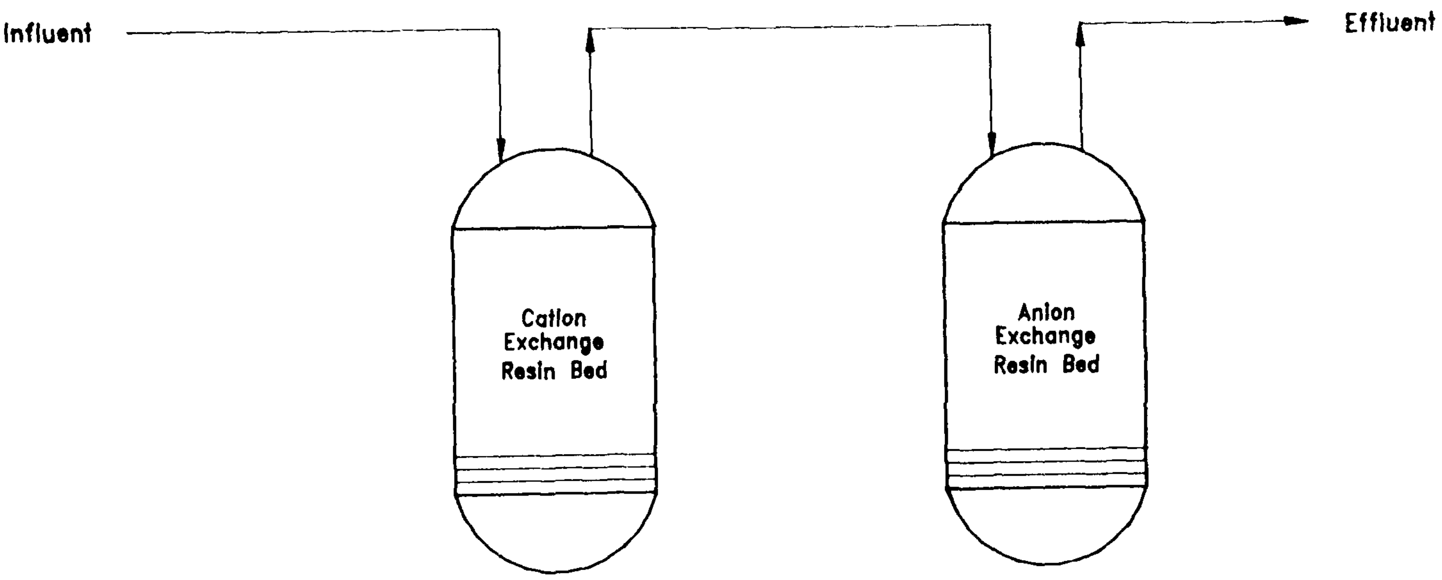
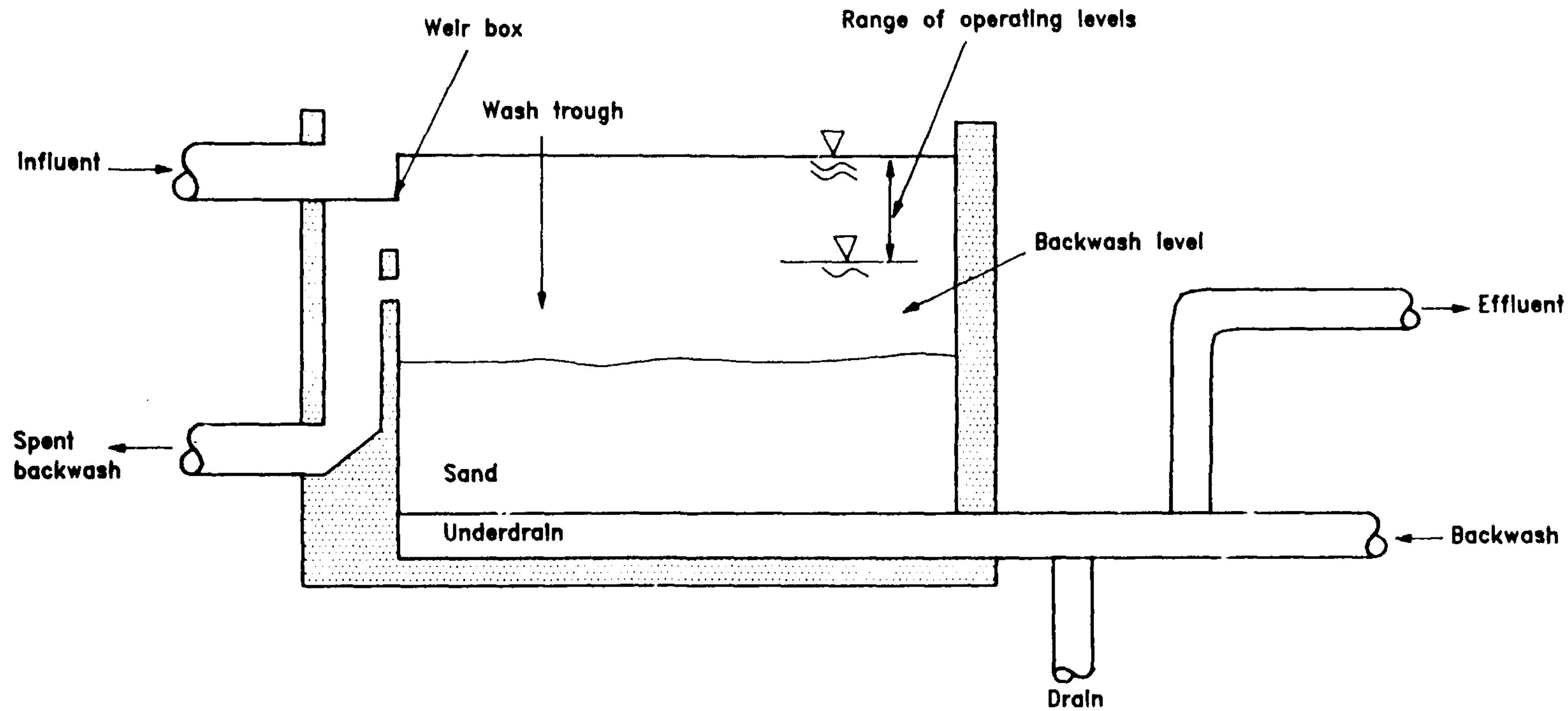


FIGURE 4-3
MILAN ARMY AMMUNITION PLANT
ION EXCHANGE PROCESS DIAGRAM



Source: Adapted from Standard Handbook of Environmental Engineering

FIGURE 4-4
MILAN ARMY AMMUNITION PLANT
GRANULAR MEDIA FILTRATION PROCESS DIAGRAM

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Dwg no.: 09229111

89% and 93% of the metals in the influent.[2] The concentrated waste, or permeate, will require additional treatment through, for example, an evaporation system. This treatment may be more complicated and expensive than the original treatment. Reverse osmosis has been demonstrated to effectively treataqueous metal wastes.

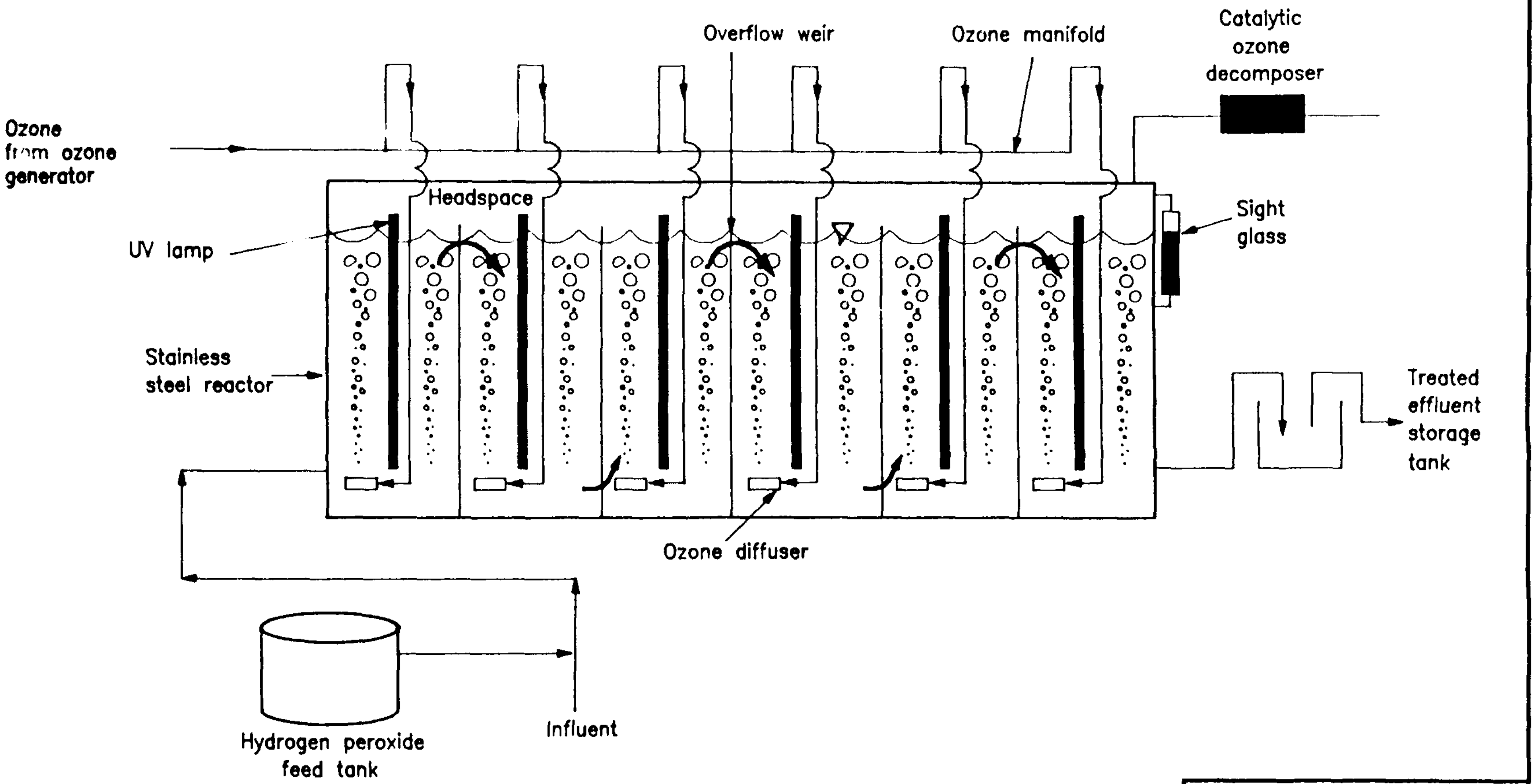
Initial Screening - Reverse osmosis may not be effective in treating inorganic contaminants found at MAAP. Operation of the unit requires skilled personnel and pretreatment requirements including the removal of organics must be addressed to avoid damaging the membrane. This process is a very high maintenance operation especially when considering the secondary treatment necessitated by the concentrated permeate. This process is eliminated from further consideration.

4.2.4.7 Ultraviolet-Oxidation. Description - Ultraviolet (UV)-oxidation is an emerging technology for destruction of organic compounds in groundwater. Commercial applications using hydrogen peroxide and ozone as the oxidants have been developed. UV light reacts with hydrogen peroxide and/or ozone molecules to form hydroxyl radicals. Two different UV-oxidation systems are offered commercially. One system distributed by Peroxidation Systems uses hydrogen peroxide with high-intensity UV lamps to maximize hydroxyl radical formation. The other, distributed by Ultrox International, uses both hydrogen peroxide and ozone, which has a higher oxidizing potential, with lower intensity lamps to form the hydroxyl radical. This very powerful chemical oxidant then reacts with the contaminants in the water. Many organic contaminants absorb UV light and become more reactive to chemical oxidants. If carried to completion, the end products of the oxidation process are carbon dioxide, water, and oxidized substances associated with the organic waste. UV-oxidation has been demonstrated to oxidize explosives as well as chlorinated and aromatic hydrocarbons. Secondary waste management is not required because organics are eliminated in the process with limited air emissions and without the generation of hazardous substances. Removal of metals from a waste stream may be necessary prior to treatment with UV-oxidation to reduce scaling and fouling.

Initial Screening - Pilot testing and full-scale applications have verified the effectiveness of UV-oxidation in treating groundwater containing a variety of organics, including explosives (USATHAMA, 1991a). In addition, previous studies elsewhere indicate that UV-oxidation could be very successful at this site. 2,4,6-TNT detected at levels of 750 μg/L have been reduced to less than 0.4 μg/L during a feasibility study conducted by Ultrox International (Ultrox, 1990). Although levels found at MAAP are considerably higher than those treated in the study, the treatment level is promising. Treatability studies are necessary to fully evaluate the effectiveness of this process. UV-oxidation is becoming a widely accepted technology due to its ability to treat various organics and the fact that it does not generate residual waste. The process is widely available and has been demonstrated to be cost effective. UV-oxidation is retained for consideration in alternatives assembly. Since the system using lower intensity lamps with both hydrogen peroxide and ozone provides greater cost effectiveness over a long-term treatment plan, due to lower electrical costs, it will be given further consideration. A concept diagram of this UV-oxidation system used by Ultrox International is given in Figure 4-5.

4.2.4.8 Precipitation. Description - Precipitation is a chemical/physical process used for removal of metals from aqueous waste streams. Precipitation involves several steps including: (1) an oxidation/reduction step in which the metal ion is adjusted to the correct valence state for the precipitation reaction; (2) a pH adjustment step to optimize the process; (3) addition of a precipitating agent; and (4) coagulation, flocculation, and sedimentation to remove the precipitates from suspension. When used prior to other treatment technologies, precipitation reduces possible process inefficiency and operational difficulties due to the presence of dissolved metals. Cr (VI) is commonly removed by reduction to Cr (III) followed by precipitation as an oxyhydroxide species. Precipitation generates a semi-solid sludge as a

[2] Information given in conversation between ICF KE and Culligan representative - January 22, 1992.



Source: Ultrox International

FIGURE 4-5
MILAN ARMY AMMUNITION PLANT
UV-OXIDATION PROCESS DIAGRAM

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by-product. This sludge may be considered hazardous waste if high concentrations of toxic metals are present, requiring off-site disposal at a permitted facility.

Initial Screening - Precipitation is a widely used and well-proven technology for treating a wide range of inorganic contaminants. Traditionally, this process has had a disadvantage since it requires the storage of large quantities of chemicals and the disposal of residuals. However, a process patented by Andco Environmental Processes avoids both these issues. Andco's process generates ferrous ions which coprecipitate soluble metals in the waste stream. Since the ferrous ions are generated through a direct current which passes through a cell containing carbon steel electrodes (i.e., an electrolytic process) the need to store chemicals is minimized, and the amount of residuals produced is reduced. Often a polymer may be added to assist in the floc formation. Precipitation processes are frequently employed for drinking water and industrial/hazardous wastewater treatment. Precipitation is retained for consideration in the alternatives assembly. A concept diagram of an electrochemical precipitation unit is given in Figure 4-6.

4.2.4.9 Neutralization. Description - The pH of a contaminated water stream is often an important parameter in implementing treatment processes. Neutralization adjusts the pH of an aqueous stream through the addition of acids or bases. Neutralization may affect the solubility or complex form of metal ions and charged organic species and, therefore, may be used as a treatment step in combination with other technologies.

Initial Screening - Some of the pH readings in groundwater at the O-Line Ponds area are low, often ranging between 4.8 - 5.8. Adjustment of pH outside the neutral range (typically 6.0 to 8.0) may be necessary to optimize some process options, such as oxidation and precipitation. This process is retained as an ancillary step for consideration in alternatives assembly.

4.2.4.10 Reduction. Description - Chemical reduction is primarily used to treat liquid waste containing Cr (VI) by reducing it to Cr (III). In this process, a reducing agent lowers the oxidation state of a compound to reduce its toxicity or solubility, or to transform it into a form which can be easily handled. Reduction often requires pH adjustment and some type of settling or precipitation procedure.

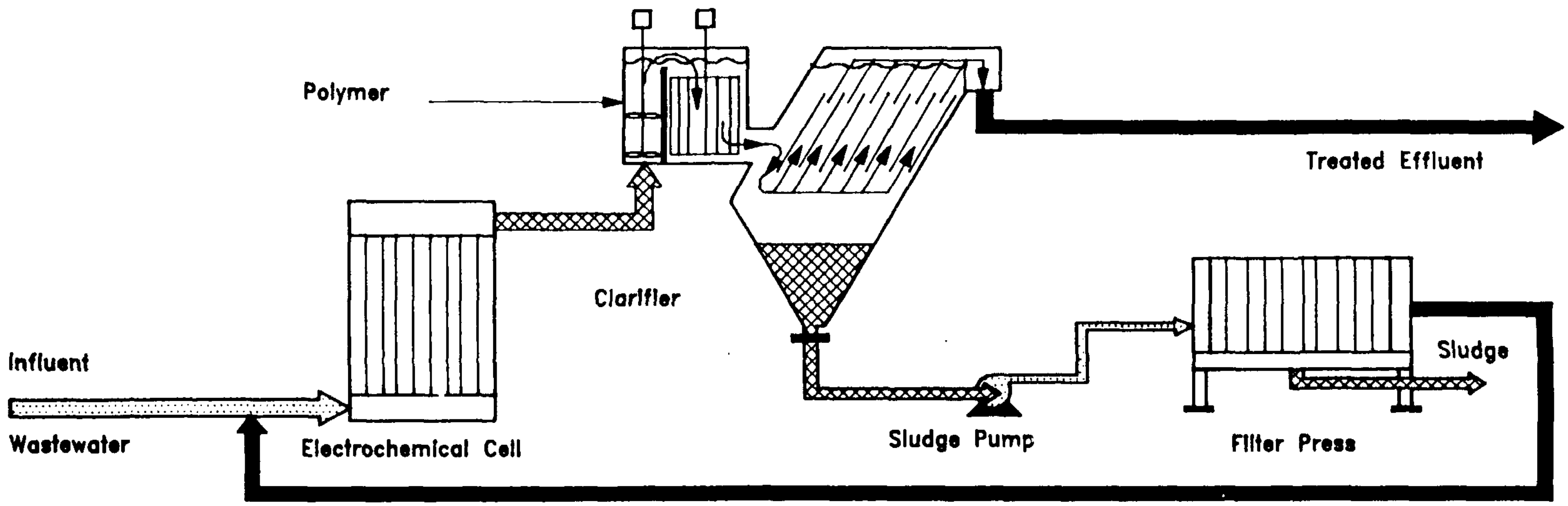
Initial Screening - Chemical reduction is well developed and directly applicable to treating chromium, a contaminant in the groundwater at the O-Line Ponds area. Reduction is retained for consideration in alternatives assembly in the event that Cr (VI) at levels exceeding ARARs is found in the extracted groundwater.

4.2.4.11 Aerobic Biological Degradation. Description - Aerobic biological degradation is achieved in the presence of oxygen. It is the most widely used biological process. Aerobic process options are activated sludge, trickling filters, rotating biological contactors, and powdered activated carbon treatment (PACT).

Activated sludge is an aerobic flocculent slurry of microorganisms which remove organic matter from wastewater and are then removed themselves, usually by sedimentation.

A trickling filter is a packed tower, fixed film reactor. Based on their ability to reduce the waste concentration at a relatively low operating cost and their ability to treat, many filters have been used as pretreatment devices for other biological operations. Rotating biological contactors are similar to trickling filters utilizing fixed film biological processes to remove organic chemicals.

PACT utilizes activated sludge in conjunction with powdered activated carbon (Zimpro/Passavant, Inc.). The activated carbon is mixed into the activated sludge tank. Many of the contaminants are adsorbed on the carbon which is removed and recycled along with the biomass in the clarifier, thereby increasing retention time.



Source: Andco Environmental Processes, Inc.

FIGURE 4-6
MILAN ARMY AMMUNITION PLANT
ELECTROCHEMICAL
PRECIPITATION
PROCESS DIAGRAM

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FAIRFAX, VIRGINIA
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Checked by: J. McKENDRY	Dwg no.:
Date: 03-30-92	09229112

Initial Screening - Treatability studies would be required to assess the effectiveness of aerobic biological degradation and to design the optimum treatment configuration. Aerobic treatment appears to be applicable for some of the organic contaminants in the groundwater at the O-Line Ponds area; however, the variety of explosive contaminants present in the groundwater makes development of a biological system capable of effectively treating the full range of explosives somewhat difficult. In addition, the degradation of explosives is not widely known. Studies have shown that although levels of 2,4,6-TNT decrease in activated sludge systems, the compound undergoes biotransformation rather than biodegradation (Burrows, et.al., 1989). Biotransformation products such as 2,4-DNT are more toxic than the original contaminant and are more difficult to degrade. RDX has not been successfully transformed through aerobic sludge treatment, although results have been seen in anaerobic processes. Representatives from EIMCO Process Equipment Company feel that the levels of organics in the groundwater at O-Line Ponds are not high enough to sustain microbial activity.[3] In addition, high concentrations of metals may be toxic to microorganisms and thus the presence of metals in groundwater at the O-Line Ponds area may affect the ability to develop a stable biological reactor system in the field. This technology is eliminated from further consideration.

4.2.4.12 Anaerobic Biological Degradation. Description - Anaerobic biological degradation is similar to activated sludge in the absence of oxygen. Anaerobic microorganisms responsible for contaminant degradation produce methane and carbon dioxide as process by-products. Anaerobic treatment systems typically produce little sludge and have a low operating cost. Anaerobic systems are widely used to treat concentrated wastes.

Initial Screening - Anaerobic systems are not as reliable as aerobic systems and are much slower. Collection and treatment of methane gas, if not recycled, is also a concern. Variations in waste stream characteristics are likely to upset the process. In addition, treatability studies may be required to determine the optimum biological treatment scheme. Anaerobic biological degradation is eliminated from further consideration.

4.2.4.13 Enhanced In-Situ Biological Treatment. Description - Enhanced in-situ biological treatment employs natural biological activity and/or genetically engineered and mutated microorganisms to attack site contaminants. Theoretically, genetically engineered organisms can be developed to feed on specific contaminants present in groundwater environments; however, release of these organisms is still in the experimental stages. Enhancement of natural biological activities is much more acceptable and is currently undergoing extensive research. Often, the microorganisms required to biologically degrade specific contaminants already exist in the aquifer, but their growth rate is limited by either a lack of oxygen (for aerobic organisms) or a lack of necessary nutrients. Injection of nutrients and/or an oxygen source may stimulate growth of the existing organisms, thus increasing the degradation rate of the site contaminants. Application of this technology would require long-term operations to develop and maintain the necessary bacterial population. Another disadvantage of this technology is that enhancement of conditions for certain biological communities may destroy other microorganisms that are responsible for the degradation of a different set of compounds.

Initial Screening - Using an in-situ process, the groundwater may be treated with little disruption to the current surface conditions. However, potential problems exist including possible degradation of compounds into more toxic or carcinogenic compounds, and the need for extensive testing, modeling, and field monitoring. For these reasons, enhanced in-situ biological degradation is eliminated from further consideration.

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[3]Information given in conversation between J. McKendry (ICF KE) and Mike Hanifey (EIMCO) - February 11, 1992.

4.2.4.14 Wet Air Oxidation. Description - Wet air oxidation involves the aqueous phase oxidation of dissolved or suspended organic contaminants at elevated temperatures and pressures. The waste stream is heated and then allowed to oxidize in the presence of oxygen. The contaminants oxidize and cause a temperature rise. Wastes in the gas phase can then be separated.

Initial Screening - Wet air oxidation is most effective on waste streams with organic concentrations above 10,000 mg/L. Its high costs are not justified by the less concentrated groundwater found at the O-Line Ponds area. Wet air oxidation is eliminated from further consideration.

4.2.5 Discharge of Groundwater

If one or more of the collection/treatment technologies are incorporated into potential alternatives, the discharge of extracted groundwater must also be addressed. Discharge options can be divided into off-site and on-site discharge.

Off-Site Discharge - Following on-site treatment of the contaminated groundwater, the treated water could be discharged into an off-site surface water body such as the Rutherford Fork. A possible advantage of this method is the relatively high baseflow, which provides greater mixing than discharge into the on-site ditches. Pretreated or untreated groundwater could also be transported off site for treatment at a commercial hazardous/industrial waste treatment facility or a publicly owned treatment works.

On-Site Discharge - Following on-site treatment of the contaminated groundwater extracted from the aquifer system, there are several available options for on-site discharge of the treated waters: re-injection into the aquifer, discharge into nearby surface water, or an on-site treatment facility.

4.2.5.1 Off-Site Discharge to Surface Water. Description - Extracted groundwater must be treated before discharge into any body of water or surface drainage course. Discharge is accomplished by means of an outfall into the water body with a diffusing section at its end to ensure adequate mixing with the receiving waters. A potential receiving body at the O-Line Ponds area is the Rutherford Fork of the Obion River.

Initial Screening - Surface water discharge following treatment is an implementable option at the O-Line Ponds area. Discharge into the Rutherford Fork is preferred over on-site discharge in the nearby drainage ditches because of the greater dilution available. In addition, the effectiveness of the groundwater extraction system can be better judged if treated groundwater is not discharged to a nearby drainage ditch (see On-Site Discharge to Surface Water below). Because this is a remedial action under CERCLA, a permit for discharge into the Rutherford Fork is not required; however, the substantive requirements of a permit must be met. Nevertheless, surface water discharge following treatment is one of the most straightforward, low cost, and implementable options. Therefore, discharge of treated groundwater to the Rutherford Fork is retained as the representative process option for consideration in alternatives assembly.

4.2.5.2 Commercial Hazardous/Industrial Waste Treatment Facility. Description - In this technology, untreated extracted groundwater would be transported off-site to a licensed commercial hazardous/industrial waste treatment facility. These facilities typically have a wide variety of unit processes for treatment of inorganic and organic waste streams, and could provide treatment of extracted groundwater and discharge/disposal of treated water under their RCRA and NPDES permits.

Initial Screening - Potential problems with this option are the increase of public risk due to transportation of materials, capacity limitations at nearby facilities, and unanticipated plant closings which would result in long-term work stoppage. Costs for transportation, treatment, and disposal at nearby

treatment facilities is more costly than on-site treatment and subsequent discharge. Therefore, off-site commercial treatment is eliminated from further consideration.

4.2.5.3 Off-Site Publicly Owned Treatment Works. Description - An off-site publicly owned treatment works (POTW) is located in the vicinity of the study area; therefore, this option is being considered. This technology consists of discharge of extracted groundwater from the O-Line Ponds area to the POTW with or without pretreatment. Depending on the distance to the nearest accessible sewer main, direct piping or transportation by tanker truck will be required to transport the extracted groundwater.

Initial Screening - The feasibility of piping or transporting a large quantity of explosives-laden water (potentially 500 gallons/minute) a distance of several miles precludes further consideration of this option. Transportation or direct piping of the large quantities of water to be generated would be costly and potentially create a risk to the public.

4.2.5.4 Re-Injection. Description - Re-injection systems are frequently used in combination with extraction wells in order to facilitate groundwater restoration where hydraulic conductivity and transmissivity are high. Re-injection systems are used to direct contaminants to the extraction wells and to accelerate groundwater restoration. Potential problems involved with the use of re-injection systems include sand clogging, plugging by chemical precipitation, and spreading of the plume.

Initial Screening - This technology appears to be implementable at the O-Line Ponds area because of the site hydrogeology; however, care must be taken in any final design phase to avoid the potential problems noted above. Since re-injected groundwater would be treated to concentrations specified by the remedial action objectives, it is expected to satisfy re-injection requirements. Re-injection is retained for consideration in alternatives assembly.

4.2.5.5 On-Site Discharge to Surface Water. Description - Treated groundwater is discharged into an on-site surface water channel. Potential on-site receiving bodies are existing drainage ditches. Discharge to these ditches is dependent on a determination of the ditches as wet weather conveyances or as streams supporting aquatic life.

Initial Screening - This discharge option would be readily implementable since drainage ditches exist close to the O-Line Ponds area. An NPDES permit is already in place for discharge into these ditches from the pink water treatment plant. This option is retained for further consideration.

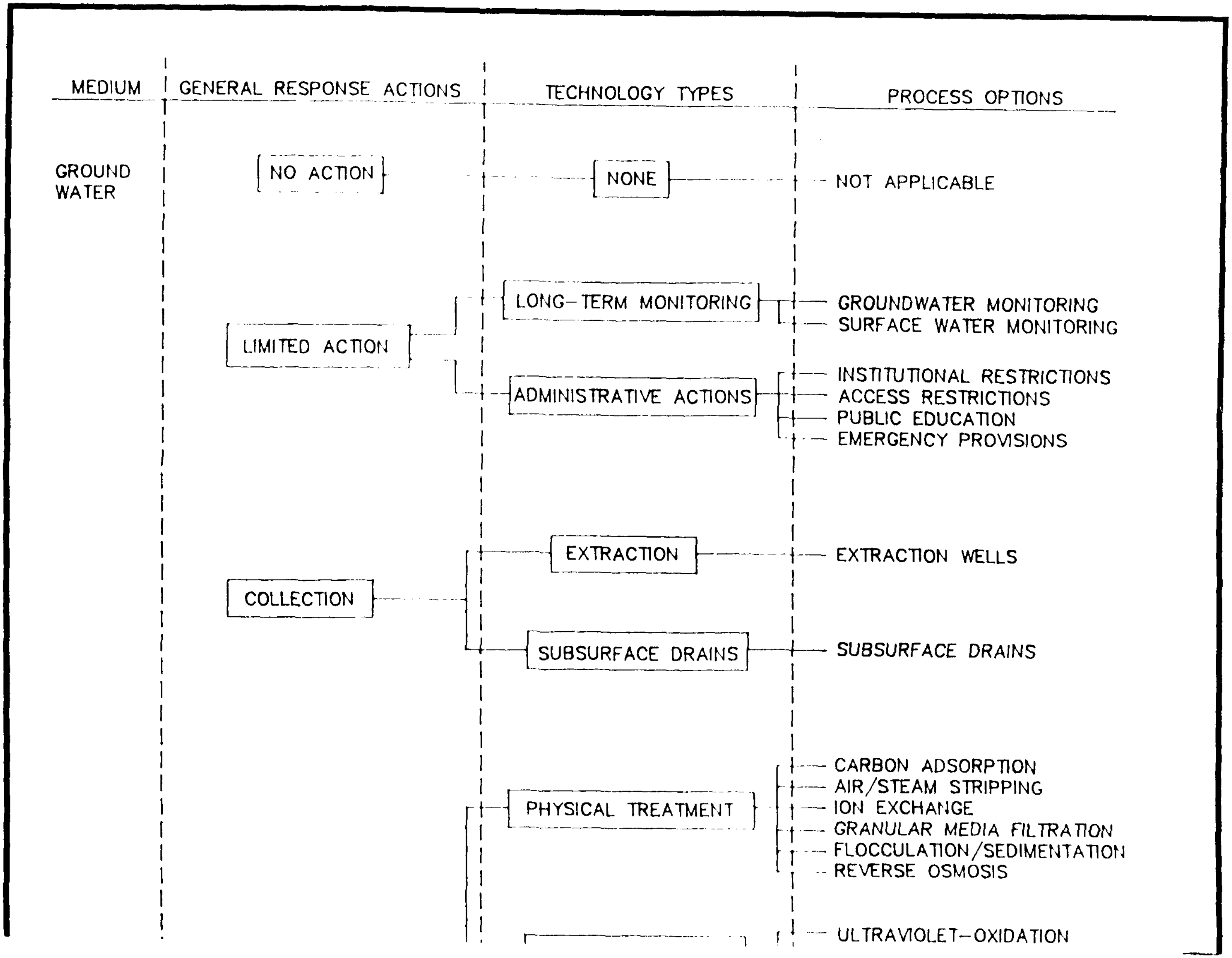
4.2.5.6 On-Site Treatment Facility. Description - Extracted groundwater is pumped to a holding tank. A flocculation agent is added to clarify the water, and the supernatant is pumped out of the holding tank into another tank mounted on a truck. The supernatant is transported to the pink water treatment facility at O-Line where it is discharged to an equalization basin. The supernatant is then treated by fabric filtration and carbon adsorption. The resulting effluent is discharged to the drainage ditch under the facility's NPDES permit.

Initial Screening - This process option is not implementable since the treatment system is designed to accommodate water only from the process plant. The treatment facility processes 20,000 gallons per week and is run at 80 gallons per minute (gpm) in batches. Due to the large volume of the contaminated aquifer and the high rate of treatment and discharge that may be implemented (approximately 500 gpm), this method of discharge is not viable. Therefore, it is eliminated from further consideration.

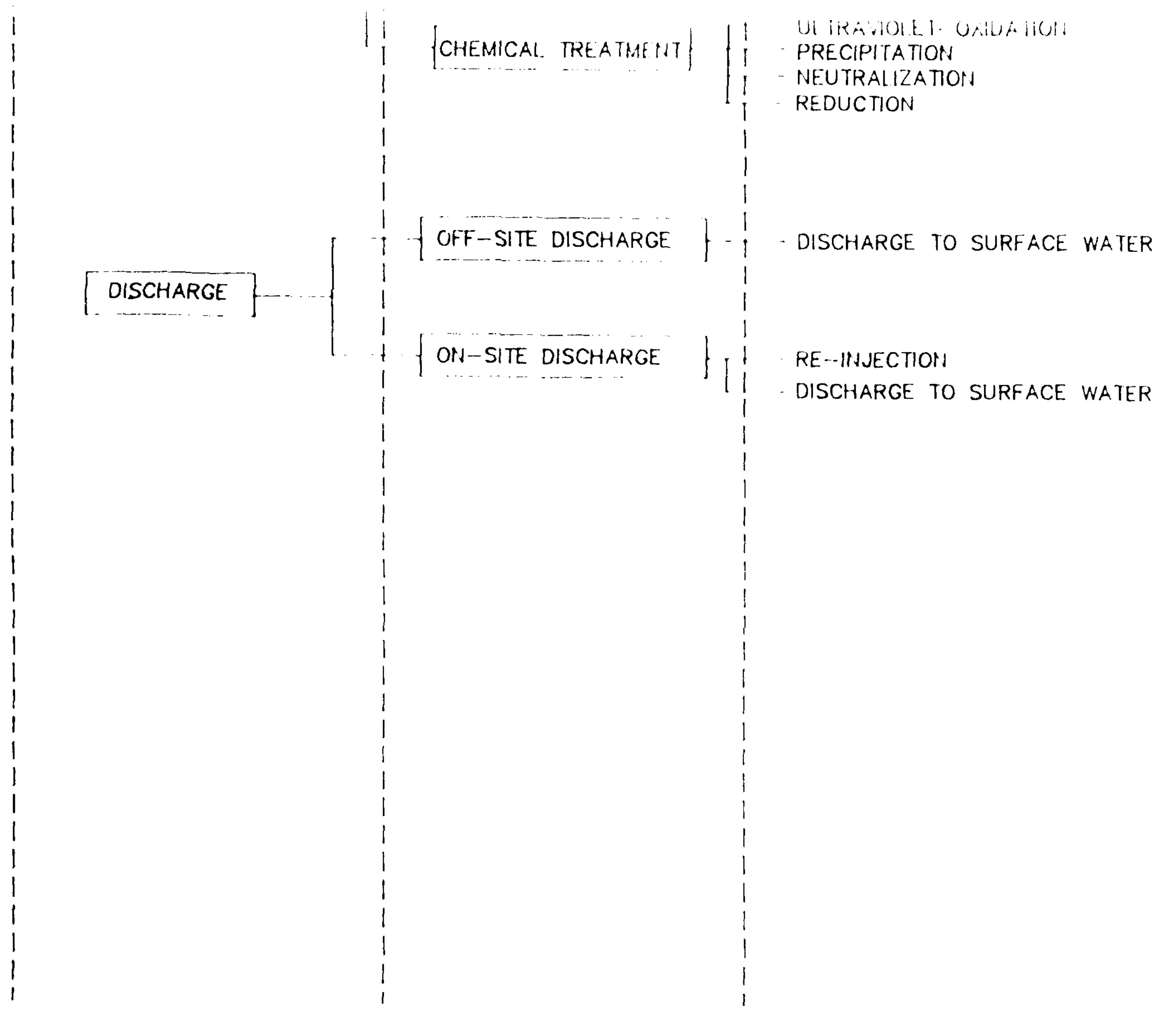
4.3 SUMMARY OF REMEDIAL TECHNOLOGY SCREENING

Remedial technologies have been identified to achieve the remedial action objectives. Each remedial technology can be implemented using several process options, and these were also identified. The remedial technologies were then screened based on implementability, effectiveness, and cost. The cost criterion was only used to eliminate those processes which are highly costly and which do not offer advantages over lower-cost options.

The remedial technologies and process options which survived the initial screening process are identified in Figure 4-7. The No Action and Limited Action response actions and relevant technology types are retained. One extraction technology, seven on-site treatment technologies, and three discharge options are retained as well. Figure 4-7 shows the general response action, technology types, and process options retained for consideration in alternatives development for groundwater remedial action. Technologies are assembled into alternatives in the Section 5.0.



MEDIUM
GENERAL RESPONSE ACTIONS
TECHNOLOGY TYPES
PROCESS OPTIONS
GROUND WATER
NO ACTION
NONE
NOT APPLICABLE
LIMITED ACTION
LONG-TERM MONITORING
GROUNDWATER MONITORING
SURFACE WATER MONITORING
ADMINISTRATIVE ACTIONS
INSTITUTIONAL RESTRICTIONS
ACCESS RESTRICTIONS
PUBLIC EDUCATION
EMERGENCY PROVISIONS
COLLECTION
EXTRACTION
EXTRACTION WELLS
SUBSURFACE DRAINS
SUBSURFACE DRAINS
PHYSICAL TREATMENT
CARBON ADSORPTION
AIR/STEAM STRIPPING
ION EXCHANGE
GRANULAR MEDIA FILTRATION
FLOCCULATION/SEDIMENTATION
REVERSE OSMOSIS
ULTRAVIOLET-OXIDATION



2

FIGURE 4-7
MILAN ARMY AMMUNITION PLANT
REMEDIAL TECHNOLOGIES RETAINED FOR ALTERNATIVE ASSEMBLY

Compiled by: ICF KAISER ENGINEERS

Drawn by:	K. CHARETTE	Project Code:	04302
Checked by:	J. McENERY	Dwg no.:	09229104
Date:	[illegible]		

5.0 DEVELOPMENT OF REMEDIAL ALTERNATIVES FOR GROUNDWATER

Development of remedial alternatives must conform to the requirements identified in CERCLA as amended and, to the extent possible, the National Contingency Plan (NCP). Section 300.68 of the NCP specifically refers to ARARs in the development of alternatives. CERCLA section 121 (d) requires that Superfund remedial actions attain ARARs or other federal statutes unless specific waivers are granted. Superfund remedial actions must also attain state requirements that are more stringent than federal requirements to the extent that they are also applicable or relevant and appropriate and are identified to the EPA in a timely manner.

CERCLA section 121 (b) identifies the following statutory preferences when developing and evaluating remedial alternatives:

- Remedial actions involving treatment which permanently and significantly reduces the volume, toxicity, or mobility of the contaminants of hazardous substances are preferred over remedial actions not involving such treatment;
- Off-site transport and disposal of hazardous substances or contaminated materials without treatment is considered to be the least favored remedial action alternative when practical treatment technologies are available; and
- Remedial actions using permanent solutions, alternative treatment technologies, or resource recovery technologies shall be assessed.

Based on these statutory preferences and the response objectives developed in Section 3.0, remedial alternatives were developed to satisfy the following criteria:

- Remedial alternatives are protective of human health and the environment;
- Remedial alternatives attain chemical-specific ARARs, and can be implemented consistently with location-specific and action-specific ARARs;
- Remedial alternatives use permanent solutions and treatment technologies to the maximum extent possible; and
- Remedial alternatives are capable of achieving a remedy in a cost-effective manner.

Technology types were screened in Section 4.0 based on three factors: implementability, to eliminate those technologies which are not feasible due to general site conditions such as aquifer depth or the size of the impacted site; effectiveness, to eliminate technologies which generally have not been proven effective in reducing the contaminants of concern at this site; and cost, to discard technologies which are very costly and do not offer advantages over other technologies. In this section, the screened technologies are assembled into remedial alternatives based on the above-listed criteria. Alternatives are incorporated into each of the following general response actions:

- No Action;
- Limited Action; and
- Groundwater Collection, On-Site Treatment, and Discharge.

Sections 5.1 and 5.2 describe Alternative T-1, No Action, and Alternative T-2, Limited Action, respectively. These two alternatives do not incorporate treatment components but provide a basis to which active

treatment alternatives may be compared. The three remaining general response actions described in Section 4.0 have been combined here to create one general response action which generates alternatives capable of meeting the above preferences and criteria. Section 5.3 discusses the development of the extraction alternative and the six treatment/discharge alternatives which are developed under this third general response action (groundwater collection, on-site treatment, and discharge).

5.1 ALTERNATIVE T-1 - NO ACTION

The No Action alternative, Alternative T-1, has been developed to provide a basis to which active treatment alternatives may be compared. This alternative is required by the NCP and CERCLA as amended. No remedial actions are involved in this alternative. The alternative provides a baseline for comparison of risk reduction achieved by each treatment alternative.

5.2 ALTERNATIVE T-2 - LIMITED ACTION

The Limited Action alternative, Alternative T-2, has been developed to provide minimal actions which may be taken to limit public exposure to the contaminated media. The toxicity, mobility or volume of contaminants are not reduced. As described in Section 4.0, such measures include institutional restrictions, public education programs, emergency provisions, long-term environmental monitoring and five-year reviews.

5.3 GROUNDWATER EXTRACTION, ON-SITE TREATMENT AND DISCHARGE

Groundwater extraction, on-site treatment and discharge is the third general response action. A general extraction alternative and six treatment/discharge alternatives are developed under this general response action. Although a groundwater extraction alternative will be used in conjunction with each potential treatment/discharge alternative, it is developed separately because the design of the groundwater extraction system will not significantly effect the selection of the treatment alternative. Discharge options have been combined with treatment alternatives because the acceptable contaminant concentrations for surface water discharge are different from the acceptable levels for re-injection.

5.3.1 Extraction Alternative

In screening technology types, extraction wells have been determined to be the only feasible technology to extract groundwater. Use of extraction wells is a widely-applied and well-understood technology that, given the highly transmissive and extensive aquifer at MAAP, can be implemented at the site. Based on the results of the aquifer testing performed during the RI, it is expected that the aquifer will support a high extraction rate and the areal extent of the corresponding steady-state cone of depression will be relatively small. High-capacity submersible pumps will, therefore, be necessary to achieve gradient reversal; however, the observed low TSS and lack of corrosive conditions are conducive to use of these pumps. It is also expected that multiple extraction wells will be necessary due to the apparent width (estimated to be 1,500 feet) of the plume. Re-injection of treated groundwater could enhance the effectiveness of the extraction well system by applying additional gradient control. A number of treatment/discharge alternatives developed below incorporate re-injection as a method of discharge.

Insufficient aquifer data are currently available to design the most effective extraction well system for the O-Line Ponds area. Further aquifer testing and groundwater modeling must be performed prior to detailed design; however, a representative extraction system, Alternative E-1, consists of six shallow extraction wells installed downgradient of the O-Line Ponds.

5.3.2 Components of On-Site Treatment/Discharge Alternatives

To assist in formulating groundwater treatment/discharge alternatives, the process options which passed the initial screening step (shown in Figure 4-7) have been grouped into the following treatment components:

- Pretreatment;
- Treatment for removal of organic contaminants;
- Treatment for removal of inorganic contaminants;
- Post treatment; and
- Discharge.

These treatment components are not always used in a sequential fashion; thus, pretreatment steps are often used to remove particulates or neutralize the groundwater stream between two treatment steps. Each treatment component is discussed below with respect to the technologies which passes the screening step.

5.3.2.1 Pretreatment. Pretreatment may prove to be necessary prior to the primary treatment processes. It is frequently more cost-effective to remove suspended solids from wastewaters using a filtration system than to deal with potential fouling of subsequent treatment units through increased maintenance. Two pretreatment options remain as a result of the initial screening of process options:

- granular media filtration (GMF); and
- precipitation.

Although the levels of suspended solids are relatively low in the groundwater at O-Line Ponds, the removal of suspended solids using GMF may be necessary prior to further treatment by carbon adsorption, ion exchange and UV-oxidation. Removal of suspended solids may also be necessary between treatment process operations, for example, following precipitation. The precipitation of heavy metals is necessary if subsequent treatment by carbon adsorption is considered.

5.3.2.2 Treatment for Removal of Organic Contaminants. The removal of explosive compounds is vital to groundwater remediation at this site. The following two technology types, which were initially screened, are retained for alternatives assembly:

- UV-oxidation; and
- carbon adsorption.

These technologies are considered because of their ability to treat the high levels of explosives detected in the groundwater to levels meeting effluent requirements. Either technology may be used by itself or in combination for organics removal. The removal of organics may be preceded by the removal of suspended solids to reduce maintenance due to system fouling.

5.3.2.3 Treatment for Removal of Inorganic Contaminants. Depending on which process is selected for the removal of organics and which process is selected for discharge, the removal of inorganics would either precede and/or follow this step. Technologies capable of removing inorganics are categorized into primary and secondary treatment steps. Secondary treatment may only be necessary if surface water discharge is selected and AWQC are imposed. The following three technologies were retained for alternatives assembly:

- precipitation, (primary treatment);

- ion exchange, (secondary treatment); and
- reduction, (secondary treatment).

If the chromium detected in the groundwater proves to be Cr(VI), reduction may be necessary.

5.3.2.4 Post Treatment. Neutralization is the only process considered under this treatment component. This process will be used to adjust pH to acceptable levels, as necessary, for surface water discharge or re-injection.

5.3.2.5 Discharge. The following discharge options were retained for alternatives assembly:

- Re-injection, which may be implemented either upgradient or downgradient of the O-Line Ponds area; or

- Discharge to surface water, which may be to either an on-site ditch or an off-site permanent stream such as the Rutherford Fork of the Obion River.

5.3.3 Treatment/Discharge Alternatives

Treatment/Discharge alternatives are developed in this section using the components outlined above. Alternatives have been formulated assuming that either of two criteria will be met:

a) Federal MCLs, Tennessee Groundwater Standards, Health Advisories, and other health-based to-be-considered guidance, including RfDs and CSF to implement groundwater re-injection; or

b) Federal Ambient Water Quality Criteria (AWQC) and Tennessee Surface Water Standards, to implement surface water discharge.

For the contaminants of concern, the major difference between the two sets of ARARs is that AWQC are significantly lower than MCLs for inorganic constituents. Therefore, those alternatives which incorporate the surface water discharge option include an additional treatment step for removal of inorganic constituents.

As described above, Alternative T-1 is the No Action alternative required by the NCP and CERCLA as amended. A Limited Action alternative, based on EPA policy, is Alternative T-2. Alternatives T-3 through T-8 are developed below.

5.3.3.1 Alternative T-3 - UV-Oxidation/Re-injection. This alternative implements UV-oxidation as the treatment process for removal of organic compounds. The following treatment components are incorporated into the alternative:

- GMF, for pretreatment;
- UV-Oxidation, for removal of organics; and
- Re-injection, for discharge.

5.3.3.2 Alternative T-4 - Precipitation/UV-Oxidation/Ion Exchange/Surface Water Discharge. This alternative is similar to Alternative T-3 in that it uses UV-oxidation to treat organics. Inorganics treatment is achieved through a combination of precipitation and ion exchange. This additional treatment is necessary to achieve surface water discharge criteria. The following components are incorporated into this alternative:

- Precipitation and GMF, for primary removal of inorganics and pretreatment;
- UV-Oxidation, for removal of organics;
- Ion Exchange, for removal of inorganics to levels below AWQC;
- Neutralization, for post treatment; and
- Surface Water Discharge.

5.3.3.3 Alternative T-5 - Precipitation/Granular Activated Carbon (GAC)/Re-Injection. Alternative T-5 implements GAC for the treatment of organics. The levels of inorganics detected in the groundwater downgradient of the O-Line Ponds during the RI indicate that the use of precipitation prior to the GAC unit may be necessary. The following components are incorporated into this alternative:

- Precipitation and GMF, for primary removal of inorganics and pretreatment;
- GAC, for removal of organics; and
- Re-injection, for discharge.

5.3.3.4 Alternative T-6 - Precipitation/GAC/Ion Exchange/Surface Water Discharge. This alternative is similar to Alternative T-5 except that it incorporates ion exchange to treat inorganics to levels acceptable for surface water discharge. The following components are used in this alternative.

- Precipitation and GMF, for primary removal of inorganics and pretreatment;
- GAC, for removal of organics;
- Ion Exchange, for secondary removal of inorganics to levels below AWQC;
- Neutralization, for post treatment; and
- Surface Water Discharge.

5.3.3.5 Alternative T-7 - Precipitation/UV-Oxidation/GAC/Re-Injection. A combination of UV-oxidation and GAC is incorporated into this alternative.

- Precipitation and GMF, for primary removal of inorganics and pretreatment;
- UV-Oxidation and GAC, for removal of organics; and
- Re-injection, for discharge.

5.3.3.6 Alternative T-8 - Precipitation/UV-Oxidation/GAC/Ion Exchange/Surface Water Discharge. As in Alternative T-7, this alternative treats organics using a combination of UV-oxidation and GAC. Ion exchange is added as a secondary treatment technology to treat inorganics to levels acceptable for surface water discharge. The following components are incorporated into this alternative:

- Precipitation and GMF, for primary removal of inorganics and pretreatment;
- UV-Oxidation and GAC, for removal of organics;
- Ion Exchange, for secondary removal of inorganics to levels below AWQC;
- Neutralization, for post treatment; and
- Surface Water Discharge.

5.4 SUMMARY OF REMEDIAL ALTERNATIVES

A general extraction alternative, Alternative E-1, has been developed. This alternative is discussed in greater detail in Section 6.0. Eight treatment alternatives including a No Action alternative, Alternative T-1; a Limited Action alternative, Alternative T-2; and six treatment/discharge alternatives, Alternatives T-3 through T-8, have been developed. A summary of these alternatives is presented in Table 5-1. Section 6.0 provides a detailed evaluation of these alternatives.

TABLE 5-1
SUMMARY OF TREATMENT ALTERNATIVES

ALTERNATIVE	COMPONENTS OF ALTERNATIVE	CAPABLE OF MEETING SURFACE WATER ARARs	CAPABLE OF MEETING GROUNDWATER ARARs
T-1	•No Action	No	No
T-2	•Limited Action	No	No
T-3	•GMF •UV-Oxidation •Re-injection	No	Yes
T-4	•Precipitation •GMF •UV-Oxidation •Ion Exchange •Neutralization •Surface Water Discharge	Yes	Yes
T-5	•Precipitation •GMF •GAC •Re-injection	No	Yes
T-6	•Precipitation •GMF •GAC •Ion Exchange •Neutralization •Surface Water Discharge	Yes	Yes
T-7	•Precipitation •GMF •UV-Oxidation •GAC •Re-injection	No	Yes
T-8	•Precipitation •GMF •UV-Oxidation •GAC •Ion Exchange •Neutralization •Surface Water Discharge	Yes	Yes

6.0 DETAILED EVALUATION OF REMEDIAL ALTERNATIVES

In this section, the extraction, treatment, and discharge alternatives developed in Section 5.0 are evaluated in detail. The assessment consists of evaluating each alternative using the nine criteria listed in the NCP. It should be noted that the costs are reasonably conservative and are based on presently available data.

6.1 NINE EVALUATION CRITERIA

Section 300.430 (e) of the NCP lists nine criteria against which each remedial alternative must be assessed. The acceptability or performance of each alternative against the criteria is evaluated individually so that relative strengths and weaknesses may be identified.

The detailed criteria are as follows:

1) Protection of human health and the environment;
2) Compliance with ARARs;
3) Long-term effectiveness and permanence;
4) Reduction of toxicity, mobility, or volume through treatment;
5) Short-term effectiveness;
6) Implementability;
7) Cost;
8) State acceptance; and
9) Community acceptance.

The NCP (Section 300.430 (f)) states that the first two criteria, protection of human health and the environment and compliance with ARARs, are "threshold criteria" which must be met by the selected remedial action. Criteria 3 through 7 are "primary balancing criteria", and the trade-offs within this group must be balanced. The preferred alternative will be that alternative which is protective of human health and the environment, is ARAR-compliant, and provides the best combination of primary balancing attributes. The final two criteria, state and community acceptance, are "modifying criteria" which are evaluated following comment on the RI/FS reports and the proposed remedial plan.

6.1.1 Protection of Human Health and the Environment

A determination and declaration that this criterion will be met by the proposed remedial action must be made in the Record of Decision (ROD); therefore, this is a threshold criterion which must be met by the selected remedy. This criterion will be met if the risks associated with the groundwater ingestion exposure pathway are eliminated, reduced, or controlled through treatment, engineering, or institutional controls, and if the remedial action is protective of the environment.

6.1.2 Compliance with ARARS

Compliance with ARARs is also a threshold criterion which must be met by the proposed remedial action. The alternative will meet this criterion if all chemical-specific, action-specific, and location-specific ARARs are met by the alternative. The alternative must meet to-be-considered guidance, such as health advisories, reference dose data for noncarcinogens, (levels set such that no appreciable risk of significant adverse health effects is indicated), and cancer slope factors for carcinogens (levels set such that the incremental individual lifetime cancer risk is within the range of 10^{-4} to 10^{-6}), if ARARs are not available. This criterion will be used to determine if all chemical-specific, action-specific, location-specific, and to-be-

considered guidances are met. For those ARARs which are not met, a determination will be made as to whether a waiver is appropriate.

6.1.3 Long-term Effectiveness and Permanence

The level of risk associated with treatment residuals and/or untreated waste after the remedial action objectives have been met will be evaluated. Components of this risk analysis include the following:

- The magnitude of residual risk will be calculated and other factors such as volume, toxicity, mobility, and propensity to bioaccumulate will be considered.

- The adequacy and reliability of controls will be considered, including the need to maintain, upgrade, or replace the groundwater treatment system.

6.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

The statutory preference for remedial actions which employ treatment technologies that significantly and permanently reduce the toxicity, mobility, or volume of the waste is addressed in this criterion. The following factors will be considered:

- The amount of hazardous materials that will be destroyed or treated;

- The degree of expected reduction in toxicity, mobility, or volume;

- The degree to which the treatment will be irreversible; and

- The type and quantity of treatment residuals that will remain following treatment.

6.1.5 Short-Term Effectiveness

The effects of the remedial alternative during construction and implementation until the remedial response objectives are met are addressed under this criterion. The following factors will be addressed:

- Protection of the community during the remedial action, including the effects of dust from excavation, transportation of hazardous materials, and air-quality impacts from on-site treatment;

- Protection of workers during the remedial action;

- Environmental impacts of the remedial action; and

- Time until remedial response objectives are achieved.

6.1.6 Implementability

The technical and administrative feasibility of implementing the remedial action will be addressed. The technical feasibility will be evaluated on the basis of ease of construction and maintenance, reliability of the selected technology, and the ease of undertaking additional remedial actions at other operable units at MAAP.

6.1.7 Cost

The capital costs, operating and maintenance costs, and present worth cost of the proposed remedial action will be considered. In addition, the accuracy of the cost estimates will be considered. Cost sensitivity analyses may be performed if it is determined that a large amount of uncertainty exists in several assumptions.

6.1.8 State Acceptance

Since State representatives have not been provided with a formal opportunity to review the detailed analysis of the remedial actions, no formal comments are available for evaluation of the "State Acceptance" criterion.

6.1.9 Community Acceptance

Since the public has not been provided with a formal opportunity to review the detailed analysis of the remedial actions, no formal comments are available for evaluation of the "Community Acceptance" criterion. It is anticipated that formal comments from the public will be provided during the 30-day public comment period for this FS report. These comments will then be addressed in the ROD and responsiveness summary.

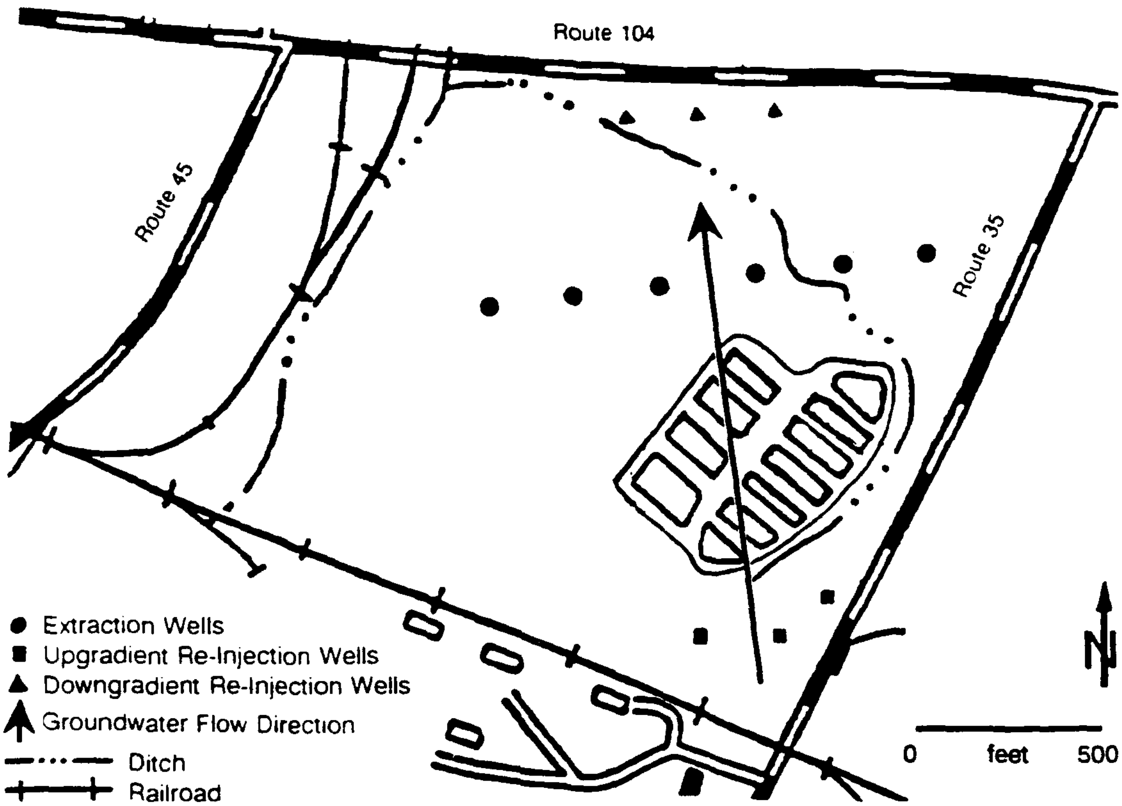
6.2 EXTRACTION ALTERNATIVE

Factors affecting the design of the extraction system are the depth and thickness of the aquifer, the conductivity of the aquifer, and the location of the contaminant plume. The highly conductive aquifer extends from the water table to a depth of approximately 260 feet below ground surface. In the plane parallel to the groundwater flow direction, the contaminant plume is approximately 3,600 feet long. Perpendicular to the flow direction the apparent width is 1,500 ft. Using these dimensions and a depth to aquifer of 45 feet, the volume of water to be extracted is 1×10^9 gallons. Because even very high extraction rates will produce only a relatively small cone of depression under these conditions, multiple wells will be needed to reverse the groundwater potential gradient over this large area. For purposes of arriving at an order-of-magnitude cost for the extraction system, a representative extraction well system design is presented and evaluated. Aquifer testing and groundwater modeling will be used to design the most efficient system. This alternative, Alternative E-1, would utilize approximately six shallow wells to achieve groundwater gradient reversal and extraction of contaminated groundwater. Six-inch wells approximately 125 feet deep are constructed of PVC. Submersible pumps are used to pump water up to ground level where additional pumps are placed to move water to the treatment site. Piping from the extraction system is made of galvanized steel to provide corrosion resistance. To prevent freezing, pipes are heated with steam injectors. The potential location of the extraction system is shown along with the proposed re-injection system locations in Figure 6-1. Costs associated with the system are presented in Table 6-1. Because a single extraction alternative has been identified, it will be combined with each treatment/discharge alternative for detailed evaluation purposes (see Section 6.3).

6.3 DETAILED EVALUATION OF TREATMENT/DISCHARGE ALTERNATIVES

Eight treatment alternatives are evaluated in detail in this section. They are as follows:

- Alternative T-1 - No Action;
- Alternative T-2 - Limited Action;
- Alternative T-3 - UV-Oxidation/Re-injection;



Source: Map adapted from USGS Topographic Map, Atwood Quadrangle, 1983.

Figure 6-1

Location of Extraction and Re-Injection Well Systems

TABLE 6-1 SUMMARY OF COSTS FOR EXTRACTION ALTERNATIVE E-1

ITEM	QUANTITY	CAPITAL COST	ANNUAL O & M COST	Present Worth of Annual Costs 30 years, 5%	Present Worth of Annual Costs 30 years, 10%
I. GENERAL ACTIONS/SITE PREPARATION					
1. Contractor Mobilization/ Demobilization		$20,000			
Subtotal:		$20,000			
II. EXTRACTION SYSTEM					
1. Extraction Wells	6 wells	$68,000			
2. Submersible Pumps (6 shallow well pumps)	6 pumps	$10,000	$13,000	$200,000	$123,000
3. Collection Piping	2870 ft	$89,000			
Subtotal:		$167,000	$13,000	$200,000	$123,000
SUBTOTAL (I, II)		$187,000	$13,000	$200,000	$123,000
III. ADDITIONAL SYSTEM COSTS					
1. Health and Safety 10% of Capital subtotal		$19,000			
2. Bid Contingency 15% of Capital subtota		$28,000			
3. Scope Contingency(p) 15% of Capital subtota		$28,000			
25% of Annual subtotal			$3,000	$46,000	$28,000
Subtotal:		$75,000	$3,000	$46,000	$28,000
CONSTRUCTION SUBTOTAL (I, II, and III)		$262,000	$16,000	$246,000	$151,000
IV. IMPLEMENTATION COST					
1. Eng. Services During Construction 15% of system subtotal		$39,000			
2. Engineering & Design 10% of system subtotal		$26,000			
Subtotal:		$65,000			
A. TOTAL CAPITAL COSTS		$327,000			
B. TOTAL ANNUAL COSTS			$16,000		
C. TOTAL PRESENT WORTH OF ANNUAL COSTS				$246,000	$151,000
TOTAL PRESENT WORTH OF CAPITAL AND ANNUAL COSTS (A + C)				$573,000	$478,000

- Alternative T-4 - Precipitation/UV-Oxidation/Ion Exchange/Surface Water Discharge
- Alternative T-5 - Precipitation/GAC/Re-injection;
- Alternative T-6 - Precipitation/GAC/Ion Exchange/Surface Water Discharge
- Alternative T-7 - Precipitation/UV-Oxidation/GAC/Re-injection.
- Alternative T-8 - Precipitation/UV-Oxidation/GAC/Ion Exchange/Surface Water Discharge

Alternative T-1 provides a baseline with which to compare other alternatives. The Limited Action alternative does not involve active treatment; it provides general precautions which limit access and exposure to the contaminated area. The remaining alternatives, T-3 through T-8, involve both groundwater treatment and discharge of treated groundwater. Alternatives T-3, T-5, and T-7 use re-injection as the discharge option; these alternatives have been designed to meet Federal MCLs, State of Tennessee groundwater standards, health advisories, and other to-be-considered guidance applicable to re-injection of groundwater. Alternatives T-4, T-6, and T-8 use surface water discharge to dispose of treated groundwater. These alternatives are expected to meet Federal Ambient Water Quality Criteria and State of Tennessee Surface Water Standards, where available. For contaminants (such as explosives) where ARARs are not available, to-be-considered health-based guidance values will be met.

6.3.1 Alternative T-1 - No Action

6.3.1.1 Description. The No Action alternative does not include any remedial activity at the site. The No Action alternative is intended to serve as a baseline with which to compare the risk reduction effectiveness of other potential alternatives. The risks to be developed in the Baseline Risk Assessment will be based upon the scenario presented by this alternative (i.e., no active reduction of present or future potential risks).

6.3.1.2 Overall Protection of Human Health and the Environment. The potential risks to human health and the environment presented in the Baseline Risk Assessment are based on the No Action alternative. The No Action alternative does not decrease the potential risks to humans or the environment in any way, as no remedial activities will be implemented at the site under this alternative. Therefore, any potential exposures posing unacceptable risk will indicate non-compliance with this criterion.

6.3.1.3 Compliance with ARARs. ARARs regulating the allowable chemical concentration levels present in groundwater will not be met in the short term. Eventually, over a long period of time, the chemical concentrations may decrease due to natural degradation and dilution. Action-specific ARARs are not considered because no remedial activities will be implemented at the site. Any ARARs not currently being met will not be met for this alternative.

6.3.1.4 Long-Term Effectiveness and Permanence. Over a long period of time, the chemical concentrations present in the groundwater may begin to decline due to natural biodegradation and dilution. However, based on the high levels of explosives presently detected, contaminants may reach off-post areas before such degradation and dilution occurs.

6.3.1.5 Reduction of Toxicity, Mobility, or Volume. There will be no remedial activities implemented at the site; subsequently, there will be no reduction of toxicity, mobility, or volume through treatment. The No Action alternative does not meet this criterion.

6.3.1.6 Short-Term Effectiveness. This criterion will not be met by the No Action alternative because no remedial activities will be implemented at the site.

6.3.1.7 Implementability. There are no implementability concerns associated with the No Action alternative because there will be no remediation activities conducted at the site.

6.3.1.8 Cost. There is no cost associated with the No Action alternative because no remediation activities will be conducted at the site.

6.3.1.9 State Acceptance. Since State representatives have not been provided with a formal opportunity to review the detailed analysis of the remedial actions, no formal comments are available for evaluation of this criterion.

6.3.1.10 Community Acceptance. Since the public has not been provided with a formal opportunity to review the detailed analysis of the remedial actions, no formal comments are available for evaluation of this criterion. It is anticipated that formal comments from the public will be provided during the 30-day public comment period for this FS report. These comments will then be addressed in the ROD and responsiveness summary.

6.3.2 Alternative T-2 - Limited Action

6.3.2.1 Description. The Limited Action alternative will include implementation of the following actions:

- Institutional Restrictions;
- Public Education Programs;
- Emergency Provisions;
- Long-term Environmental Monitoring; and
- Five-year Reviews.

Institutional controls will include access restrictions, deed restrictions, and land use restrictions. Access restrictions will include legislation to levy fines against trespassers. Deed and land use restrictions will limit the future uses at the site and require permits, qualified supervision, and health and safety precautions for any activities conducted in the vicinity of the site. Education programs will be developed to inform workers and local residents of the potential site dangers. In addition, emergency provisions and contingency plans will be developed for the site. These provisions will provide a plan of action in the event of an accidental exposure or sudden increase in risks at the site.

Long-term environmental monitoring will be conducted at the site. Groundwater samples will be collected quarterly from existing monitoring wells and analyzed for priority pollutants and explosives. If the data collected provide evidence of continued chemical migration, further sampling may be conducted in the nearby surface waters and supplementary monitoring wells may be constructed. The data collected will be reviewed at a minimum of every five years. Five-year reviews are required by the NCP at all sites where hazardous chemicals remain untreated. The review will analyze the data collected and make a determination as to whether additional remedial actions are required at the site.

6.3.2.2 Overall Protection of Human Health and the Environment. This alternative will provide a minimal level of protection to human health and the environment by limiting future use and development of the affected groundwater resources. This alternative will not include action to reduce, eliminate, or contain the source, or to reduce migration. Monitoring will be implemented to assess data trends and to observe off-site migration, but an indeterminate amount of time will elapse between detection of a significant deterioration of site conditions and the implementation of mitigating measures. During this time, increased public health and environmental hazards will exist. This criterion will be met for the Limited Action alternative only if a strong and continuing program of controls and monitoring can be assumed.

6.3.2.3 Compliance with ARARs. All active components of this alternative will be in compliance with action-specific ARARs; however, the Limited Action alternative will not comply with chemical-specific

ARARs because contaminated groundwater will continue to migrate toward points of consumption or discharge zones. Although monitoring is performed, there is a potential for site conditions to deteriorate significantly without being detected for several months. As with the No Action alternative, the chemical concentrations present in the groundwater may naturally decrease over a long period of time due to natural degradation and dilution.

6.3.2.4 Long-Term Effectiveness and Permanence. Since no treatment or containment of the contaminated groundwater will be implemented, the risks identified in the Baseline Risk Assessment will not be mitigated in the short term. However, the chemical concentrations in the groundwater may be reduced over many years by natural degradation and dispersion. This natural remediation process will take several decades or longer to reduce the chemical concentrations below acceptable levels.

The institutional controls proposed for this alternative are not as effective as active engineering controls because they could be disregarded by individuals unfamiliar with them. The monitoring wells may require periodic servicing or replacement. For purposes of costing, however, it is assumed that the existing monitoring wells will last at least 30 years.

6.3.2.5 Reduction of Toxicity, Mobility or Volume. There will be no reduction in the toxicity, mobility, or volume of the chemically affected groundwater at O-Line Ponds area because removal or treatment of contaminated groundwater are not components of this alternative.

6.3.2.6 Short-Term Effectiveness. Institutional controls and other provisions of this alternative likely will be effective at minimizing risks in the short term. Workers responsible for collecting groundwater samples potentially could be exposed to the chemicals present in the groundwater. However, the alternative will include equipping workers with the proper personal protection equipment, including respirators to minimize potential exposure.

Implementation of this alternative will not create any adverse environmental impact. It is anticipated that all components of Alternative T-2 could be implemented within one year of the initiation of remedial activities planning.

6.3.2.7 Implementability. All components of Alternative T-2 are feasible and easily implemented. Routine sampling procedures and analysis are used for this alternative. All necessary equipment and materials required for implementation of this alternative are readily available.

Implementation of Alternative T-2 will not affect the ability to undertake additional future actions at the site. In fact, all components of Alternative T-2 are also components of each of the on-site treatment alternatives evaluated for O-Line Ponds.

Administrative implementation of Alternative T-2 will require coordination between MAAP, the TDEC, and the USEPA to ensure continuity of the long-term management and monitoring of the site.

6.3.2.8 Cost. Assuming no new monitoring wells are required, the estimated capital cost for this alternative is $49,000 as shown in Table 6-2. Annual O&M costs are $171,000. The majority of the cost for Alternative T-2 is attributable to the groundwater monitoring program that will be implemented as a component of the alternative. Contingencies associated with the alternative will be minimal as the alternative does not include any complex treatment or design components. Costs could be affected significantly if more (or less) wells are sampled, or if the cost of analysis escalates. The additional cost associated with rising analytical costs is probably balanced by the decreased range of chemicals analyzed over time. As more data are collected at the site, it will be possible eventually to identify a few indicator chemicals and reduce the total analytical costs by eliminating analysis for some compounds. Cost calculation sheets are provided in Appendix C.

TABLE 6-2 SUMMARY OF COSTS FOR ALTERNATIVE T 2 LIMITED ACTION

ITEM	QUANTITY	CAPITAL COST	ANNUAL O & M COST	Present Worth of Annual Costs 30 years, 5%	Present Worth of Annual Costs 30 years, 10%
I. Administrative Actions					
1. Institutional Restrictions/Emergency Provisions (a)		$15,000			
2. Public Education Program (b)		$20,000			
Subtotal:		$35,000			
II. LONG-TERM MONITORING & REVIEW					
1. Quarterly Groundwater Monitoring and Reporting (c)	6 wells		$67,000	$1,030,000	$632,000
2. Quarterly Surface Water Monitoring & Reporting (d)			$67,000	$1,030,000	$632,000
3. Five-Year Reviews ($15,000 ea)	6 reports		$3,000	$46,000	$28,000
Subtotal:			$137,000	$2,106,000	$1,292,000
SUBTOTAL (I, II)		$35,000	$137,000	$2,106,000	$1,292,000
III. ADDITIONAL SYSTEM COSTS					
1. Health and Safety 10% of Capital subtotal		$4,000			
2. Bid Contingency 15% of Capital subtotal		$5,000			
3. Scope Contingency 15% of Capital subtotal		$5,000			
25% of Annual subtotal			$34,000	$523,000	$321,000
Subtotal:		$14,000	$34,000	$523,000	$321,000
CONSTRUCTION SUBTOTAL (I, II, III, IV AND V)		$49,000	$171,000	$2,629,000	$1,613,000
VII. IMPLEMENTATION COST					
1. Eng. Services During Construction 0% of system subtotal		$0			
2. Engineering & Design 0% of system subtotal		$0			
Subtotal:		$0			
A. TOTAL CAPITAL COSTS		$49,000			
B. TOTAL ANNUAL COSTS			$171,000		
C. TOTAL PRESENT WORTH OF ANNUAL COSTS				$2,629,000	$1,613,000
TOTAL PRESENT WORTH OF CAPITAL AND ANNUAL COSTS (A + C)				$2,678,000	$1,662,000

TABLE 6-2 SUMMARY OF COSTS FOR ALTERNATIVE T-2 - LIMITED ACTION

NOTES AND ASSUMPTIONS

(a) - For controlling access to contaminated areas, restricting future property use, and restricting the drilling of new drinking water wells.
(b) - To increase public awareness of hazards through press releases, presentations, and posting of signs.
(c) - The cost for well sampling is $2260 per sampling event. Six (6) wells are proposed. The analytical costs are $2000 per sample, tested for TAL/TCL, explosives and cyanide.
(d) - The costs for surface water sampling is $2260 per sampling event. Six locations are proposed to be monitored quaterly. Surface water will be tested for TAL/TCL, explosives and cyanide at a cost of $2000 per sample.

6.3.2.9 State Acceptance. Since State representatives have not been provided with a formal opportunity to review the detailed analysis of the remedial actions, no formal comments are available for evaluation of this criterion.

6.3.2.10 Community Acceptance. Since the public has not been provided with a formal opportunity to review the detailed analysis of the remedial actions, no formal comments are available for evaluation of this criterion. It is anticipated that formal comments from the public will be provided during the 30-day public comment period for this FS report. These comments will then be addressed in the ROD and responsiveness summary.

6.3.3 Alternative T-3 - UV-Oxidation/Re-injection

6.3.3.1 Description. This alternative incorporates UV-oxidation for the treatment of groundwater contaminants to levels acceptable for re-injection into the aquifer. Figure 6-2 shows a flow diagram for this alternative. Water from the extraction system is filtered using a GMF. Typically such a system can remove 75% of the suspended solids assuming a 2-8 gallon/min/ft^2 filtration rate (Corbitt, 1990). Using the flow rate of the proposed treatment unit (500 gpm), a system having approximately 100 sq. ft. of cross sectional area and 2-4 feet deep is necessary. This removal percentage should be adequate pretreatment to eliminate solids which may hinder the subsequent UV-oxidation system. When suspended solids begin to appear in the effluent beyond acceptable levels for feed to the UV-oxidation unit, the filter must be backwashed to remove particles which have accumulated on the granular media. These solids will require laboratory characterization to determine proper disposal.

Representatives from Ultrox International, a leading UV-oxidation supplier, did not express concern over the levels of metals (in particular, iron and manganese) detected during the RI in the O-Line Ponds area groundwater. The highest levels observed during the RI were approximately 5.8 mg/L Fe and 1.2 mg/L Mn. Ultrox's UV-oxidation system can function effectively with up to 8 mg/L of either of these metals. Unless iron and manganese levels are shown to be significantly higher in future analyses, treatment of metals prior to UV-oxidation should not be necessary.

After pretreatment with GMF, hydrogen peroxide is added to the stream and the water undergoes a pre-oxidation step prior to UV irradiation. This step is implemented to reduce the amount of radiation needed, since the electricity for the lamps is a large portion of the system's total cost. After the pre-oxidation step, groundwater flows through a reactor which contains a series of baffles holding several UV lamps. Ozone is uniformly diffused from the base of the reactor and aids further in the oxidation process by creating hydroxyl radicals. This reaction is catalyzed by UV irradiation. Having a higher oxidation potential than hydrogen peroxide or ozone, these hydroxyl radicals in turn react more readily with the organics. If complete oxidation is achieved, organic contaminants are oxidized to carbon dioxide, nitrogen, water and salts. Excess ozone is converted to oxygen using a nickel-based catalytic converter prior to being vented to the atmosphere (HMC, 1990). Since small chain aliphatics may be formed as intermediates if complete oxidation is not achieved, the pH may need to be adjusted after treatment by UV-oxidation. Ultrox has achieved complete oxidation of explosive compounds such as 2,4,6-TNT (Ultrox, 1990). If, during treatability studies, it is determined that intermediates are being formed, a GAC system may be implemented to remove these organics. Although these intermediates may not be toxic, the addition of the GAC unit may be desirable prior to discharge.

Treated water will be pumped to a re-injection system upgradient or downgradient of the extraction system (see Figure 6-1). The location and design of the re-injection well field are dependent on aquifer tests and modeling results. Re-injection wells made of PVC will be screened along the entire depth of the aquifer (approximately 200 feet in length) to ensure proper injection into the aquifer. Galvanized steel pipes will carry water from the treatment site to the re-injection system. Steam injectors presently used on site to heat conduit, will also be used in this application.

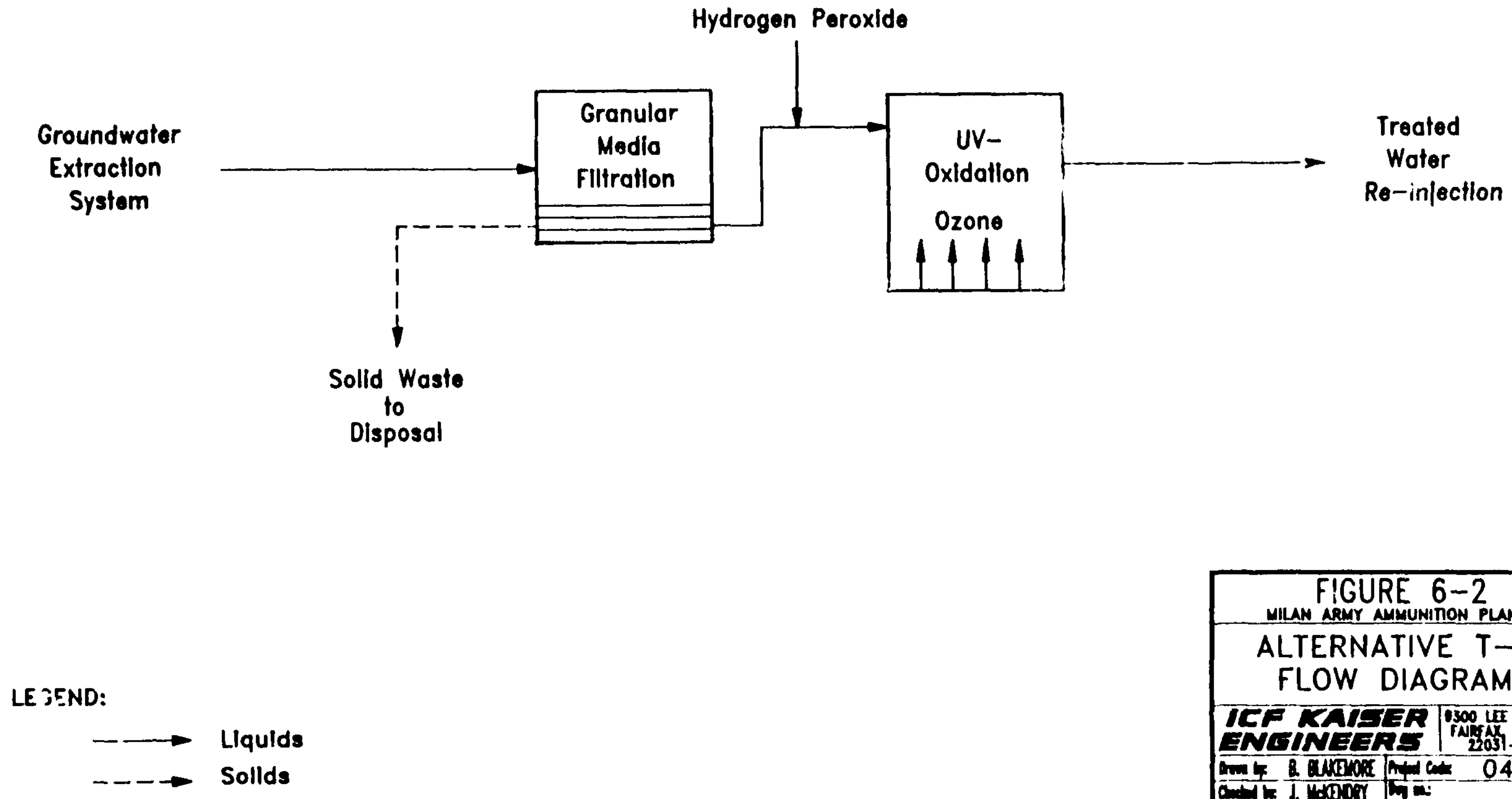


FIGURE 6-2
MILAN ARMY AMMUNITION PLANT
ALTERNATIVE T-3
FLOW DIAGRAM

ICF KAISER ENGINEERS
9300 LEE HIGHWAY
FAIRFAX, VIRGINIA
22031-1207

Drawn by:	B. BLAKEMORE	Project Code:	04302
Checked by:	J. McKENDRY	Dwg no.:	09229105
Date:	03-24-92		

6.3.3.2 Overall Protection of Human Health and the Environment. This alternative, if properly implemented and optimized, has the potential to reduce the chemical concentrations in the groundwater to below the selected cleanup criteria, thus adequately protecting human health and the environment. Cleanup criteria are based on groundwater ARARs and TBCs. Active remediation of the contaminated groundwater will be provided by this alternative, thus reducing future risk associated with the site. During the remediation activities, public health will be adequately protected through restriction of groundwater use and proper monitoring of potentially affected media.

6.3.3.3 Compliance with ARARs. It is assumed that this alternative will be operated in accordance with all Federal and Tennessee treatment facility requirements. It is also assumed that the chemical-specific ARARs specified for groundwater treatment, whether they are statutory or risk based, are sufficiently low to also meet re-injection (groundwater) discharge requirements. The treatment system itself, if properly implemented, will reduce chemical concentrations to below the specified target levels for each chemical present in the groundwater. However, since this alternative does not include a process for inorganics removal, chemical-specific ARARS may not be met if levels of inorganics increase over time. Assuming levels of inorganics do not increase to concentrations such that the treatment facility cannot remediate groundwater to levels sufficient for re-injection, this alternative is expected to comply with all ARARs and TBCs related to the groundwater medium.

6.3.3.4 Long-Term Effectiveness and Permanence. The treatment processes incorporated into this alternative should be capable of providing long-term effectiveness and permanence. The oxidizing ability of the UV-oxidation system is highly dependent on the amount of hydrogen peroxide and ozone injected into the system. Because of this, there is flexibility in the system's ability to oxidize organic contaminants. If, for instance, levels of organics are observed to increase in the future, greater quantities of hydrogen peroxide and ozone may be added to the system for greater oxidizing capabilities. In addition, extra UV lamps may be added to aid in the formation of hydroxyl radicals which further enhance organics destruction and to increase reaction holding time. Influent and effluent samples will be taken on a regular basis to evaluate the proper dosages of hydrogen peroxide and ozone and the proper holding time.

Virtually no residuals requiring disposal are generated as a result of this alternative. One advantage that UV-oxidation has over other methods of organics treatment is the ability to eliminate contaminants through oxidation rather than transferring them to another medium. Through the oxidizing capabilities of hydrogen peroxide, ozone and the hydroxyl radicals formed as a result of the UV irradiation, explosives and other organics can be fully oxidized to carbon dioxide, nitrogen, water, and salts. However, proper dosages of hydrogen peroxide and ozone must be provided as well as adequate holding time to ensure full oxidation of these contaminants. If oxidation is not complete, small chain aliphatic compounds, organonitrogen intermediates and other undesirable by-products may form. These organics are typically in the form of acids. The intermediates may effect the pH of the treated water rendering it necessary to neutralize the effluent prior to discharge. It is possible that some intermediate compounds may be toxic, in which case a GAC unit may be necessary to remove these compounds.

The granular media filtration system used for pretreatment may occasionally need to be backflushed. Suspended solids which accumulate may be drained and disposed. The solids are not expected to be hazardous but the backflushed material will be tested using the toxicity characteristic leaching procedure (TCLP). It is not expected that hazardous residuals will be produced unless explosives or other organics adsorb to the filter media.

The actual effectiveness of this alternative for the O-Line Ponds area groundwater cannot be determined without treatability testing to determine the chemical removal efficiencies of the UV-oxidation equipment. As stressed above, the system's capabilities are highly dependent on design parameters such as hydrogen peroxide dosage, ozone generation, the intensity of UV irradiation for full oxidation, and

holding time. As discussed in Section 4.0, UV-oxidation has been demonstrated to remove 2,4,6-TNT and RDX to levels below 1 μg/L (HMC, 1990). However, considering the high levels of explosives which will be encountered in the influent (as much as 26 mg/L 2,4,6-TNT was detected during the RI) and the extremely low health advisories to which the groundwater must be treated, the effectiveness of this process must be demonstrated through treatability testing.

6.3.3.5 Reduction of Toxicity, Mobility or Volume. This alternative will address the principal threats posed by the organic contaminants in the groundwater. Since it is believed that UV-oxidation will not be affected adversely by the level of inorganic constituents in the groundwater (based on the levels observed during the RI), inorganics removal is not necessary for pretreatment. Therefore, inorganics will not be treated with this alternative since levels detected during the RI do not exceed groundwater ARARs.

UV-oxidation will destroy the organic contaminants present in the groundwater. Therefore, the volume of the contaminants will be reduced. Assuming that full oxidation is achieved, contaminants are broken down into harmless products: carbon dioxide, nitrogen, water and salts. Since the molecular bonds which once held the organics together are destroyed, this process is not reversible and the toxicity of the contaminants is reduced or eliminated. The mobility of the contaminants is reduced through the effective implementation of an extraction and re-injection system. The specific design of this system is dependent on modeling and aquifer testing results.

Residuals drained from the granular media filtration unit are not expected to be hazardous. However, characterization will be required to ensure that the waste solids are disposed properly.

6.3.3.6 Short-Term Effectiveness. Construction of the extraction system, treatment facility and discharge system will be completed with standard construction equipment and will not entail additional risks to workers beyond those risks inherent in construction projects. Likewise, employees and the community located within the vicinity of the site will be unaffected by the construction of the treatment facility.

Because of the rather large size of the treatment system, its design and construction may take 12-24 months. This time estimate includes the treatment system design and review, preparation of bid packages, selection of contractors and equipment suppliers, installation, and start-up.

6.3.3.7 Implementability. The treatment processes combined in this alternative are commonly used in water and wastewater treatment systems, are proven, and commercially available. Although commercially available, UV-oxidation systems are produced by only a few vendors, each with its own designs which differ greatly from one another. Because of the variables involved in the UV-oxidation system, the unit has the flexibility to be readily adjusted if necessary in the future. Electricity and water are required to run this system, and both are available at the site. An operator will be required for approximately one-eight hour shift per day to perform inspections of the UV-oxidation system and filtration system and sampling (see Appendix C).

Due to the long period of treatment anticipated, extensive administrative oversight will be required to ensure the proper operation and maintenance and overall performance of the preferred alternative. Long-term monitoring of influent and effluent concentrations, residual characteristics, and the effectiveness of the alternative will be required. Five year reviews will also be required as part of the long-term monitoring program. Although complicated and time consuming, the tasks associated with coordinating the management of this alternative are feasible and implementable.

6.3.3.8 Cost. A summary of the costs for this alternative are given in Table 6-3. The total capital cost for the treatment system for Alternative T-3 is $1,503,000. Additional capital costs include $206,000 for site preparation and $451,000 for the installation of a re-injection system. The total present worth of

TABLE 6-3 SUMMARY OF COSTS FOR ALTERNATIVE T-3: UV OXIDATION/ RE-INJECTION

ITEM		QUANTITY	CAPITAL COST	ANNUAL O & M COST	Present Worth of Annual Costs 30 years, 5%	Present Worth of Annual Costs 30 years, 10%
I. Administrative Actions						
1. Institutional Restrictions/Emergency Provisions (a)			$15,000			
2. Public Education Program (b)			$20,000			
3. Program Oversight (c)				$75,000	$1,153,000	$707,000
Subtotal:			$35,000	$75,000	$1,153,000	$707,000
II. GENERAL ACTIONS/SITE PREPARATION						
1. Parking/Staging Area (d)		1200 sq ft	$1,000			
2. Treatment System Building Construction (e)		7500 sq ft	$150,000			
3. Building Lighting and Heating (f)			$35,000	$7,000	$108,000	$66,000
4. Contractor Mobilization/ Demobilization			$20,000			
Subtotal:			$206,000	$7,000	$108,000	$66,000
III. GROUNDWATER TREATMENT SYSTEM						
1. Pre-treatment System (GMF) (g)			$95,000	$53,000	$815,000	$500,000
2. UV-Oxidation Unit (h)			$1,400,000	$526,000	$8,086,000	$4,959,000
3. Part-time System Operator (i)		2180 hrs/yr	$8,000	$44,000	$676,000	$415,000
Subtotal:			$1,503,000	$623,000	$9,577,000	$5,874,000
IV. RE-INJECTION SYSTEM						
1. Injection Wells		3 wells	$99,000	$5,000	$77,000	$47,000
2. Horizontal Pumps		3 pumps	$11,000	$26,000	$400,000	$245,000
3. Discharge Piping		4450 ft	$316,000			
4. System Controls			$25,000			
Subtotal:			$451,000	$31,000	$477,000	$292,000
V. LONG-TERM MONITORING & REVIEW						
1. Weekly Effluent & Monthly Residuals Monitoring (j)			$200,000	$121,000	$1,860,000	$1,141,000
2. Quarterly Groundwater Monitoring and Reporting (k)		6 wells		$67,000	$1,030,000	$632,000
3. Quarterly Surface Water Monitoring & Reporting (l)				$67,000	$1,030,000	$632,000
4. Five-Year Reviews ($15,000 ea)		6 reports		$3,000	$46,000	$28,000
Subtotal:			$200,000	$258,000	$3,966,000	$2,433,000
SUBTOTAL (I, II, III, IV, and V)			$2,395,000	$994,000	$15,281,000	$9,372,000
VI. ADDITIONAL SYSTEM COSTS						
1. Health and Safety	10% of Capital subtotal		$240,000			
2. Bid Contingency	15% of Capital subtotal		$359,000			
3. Scope Contingency	15% of Capital subtotal		$359,000			
	25% of Annual subtotal			$24[illegible],000	$3,828,000	$2,347,000
Subtotal:			$958,000	$[illegible]49,000	$3,828,000	$2,347,000
CONSTRUCTION SUBTOTAL (I, II, III, IV,V and VI)			$3,353,000	$1[illegible]3,000	$19,109,000	$11,719,000
VII. IMPLEMENTATION COST						
1. Eng. Services During Construction	15% of system subtotal		$503,000			
2. Engineering & Design	10% of system subtotal		$335,000			
3. Permitting/ Coordination (m)			$25,000			
Subtotal:			$863,000			
A. TOTAL CAPITAL COSTS			$4,216,000			
B. TOTAL ANNUAL COSTS				$1,243,000		
C. TOTAL PRESENT WORTH OF ANNUAL COSTS					$19,109,000	$11,719,000
TOTAL PRESENT WORTH OF CAPITAL AND ANNUAL COSTS (A + C)					$23,325,000	$15,935,000

TABLE 6-3 SUMMARY OF COSTS FOR ALTERNATIVE T 3: UV OXIDATION/ RE-INJECTION

NOTES AND ASSUMPTIONS

(a) - For controlling access to contaminated areas, restricting future property use, and restricting the drilling of new drinking water wells.
(b) - To increase public awareness of hazards through press releases, presentations, and posting of signs.
(c) - Costs include the annual salary of one program oversight manager for the groundwater treatment program. Costs do not include government oversight of this task.
(d) - 30 ft x 40 ft staging area of 8" deep gravel.
(e) - Includes a 75 ft x 100 ft prefabricated steel building, 6" concrete base, insulation, electrical wiring, and plumbing.
(f) - Lighting consists of 25 - 8' fluorescent lights.
(g) - Pretreatment system consists of granular media filtration unit. Includes 3 vessel multi-media filter skid with pumps, influent and effluent tanks. Operating costs of $0.20/ 1000gal wastewater.
(h) - Includes 3 5000gal contactors, 4 reactors, and ozone generator. Operating costs include hydrogen peroxide, ozone, and electrical costs.
(i) - Part-time system operator is assumed to cost $20/hr and is used approximately 1 8hr shift per day. Two months operator training has been included as a capital cost.
(j) - Sixty effluent samples will be taken per year and analyzed for TAL/TCL, explosives, and cyanide. The analytical costs are $2000 per sample. The residual samples (24/year) will be tested for TCLP metals and VOCs, corrosivity, ignitability and reactivity at a cost of $700 per sample. Capital costs include 100 additional samples for TAL/TCL, explosives and cyanide which will be needed during system start-up.
(k) - The cost for well sampling is $2260 per sampling event. Six (6) wells are proposed. The analytical costs are $2000 per sample, tested for TAL/TCL, explosives and cyanide.
(l) - The cost for surface water sampling is $2260 per sampling event. Six locations are proposed to be monitored quarterly. Surface water will be tested for TAL/TCL, explosives and cyanide at a cost of $2000 per sample.
(m) - Cost includes permit application process and/or coordination with state/federal officials regarding discharge of treated water.

this alternative is estimated to be approximately $23,325,000 (30 years, 5% discount rate), including capital costs of $4,216,000 and annual O&M expenditures of $1,243,000. These costs are preliminary and are subject to change depending on modeling, aquifer testing and treatability tests. Initial costs are based on vendor information, and generic unit costs. Cost calculation sheets are provided in Appendix C.

The capital cost for the UV-oxidation unit will be affected by the selected flow rate and the inlet contaminant concentrations. If the flow rate is lower than that assumed and the contaminant concentrations are held constant, a smaller unit (i.e., to maintain the same required residence time) can be designed. Similarly, if the flow rate is higher than that assumed and the contaminant concentrations are held constant, a larger unit or multiple small units in series (i.e., to maintain the same required residence time) can be designed. Although the size of the unit will affect the capital cost of the unit, cost versus flow rate is not a linear function due to economies of scale. The contaminant concentrations affect the required residence time which affects the size of the equipment. If flow rate is held constant and contaminant concentrations are lower than that assumed, a smaller unit can be designed since less time is required to destroy the lower concentration of contaminants. If the flow rate is held constant and the contaminant concentrations are higher than that assumed, a larger unit can be designed.

The operating costs of the UV-oxidation unit are affected by the flow rate and inlet contaminant concentrations. The two most significant operating costs are electricity and oxidant consumption. Since oxidant is not added in stoichiometric quantities, the effects of contaminant concentrations on oxidant addition rates can only be determined through treatability testing. If contaminant concentrations are held constant and the flow rate is higher than that assumed, oxidant usage rates will increase proportionately since the oxidant dosage (i.e., milligrams of oxidant per liter of groundwater) should not change. If contaminant concentrations are held constant and the flow rate is lower than that assumed, oxidant usage rates will decrease proportionately.

Electrical consumption is directly related to the residence time of the groundwater in the unit and the groundwater flow rate (i.e., the size of the unit). If the flow rate is held constant and the contaminant concentrations are lower than that assumed, the required residence time in the reactor will be reduced thereby lowering electrical consumption. Similarly, if the flow rate is held constant and the contaminant concentrations are higher than that assumed, the required residence time in the reactor will be increased thereby increasing electrical consumption. The effects of contaminant concentrations on required residence time in the reactor can be estimated using reaction kinetics data developed during treatability testing. If contaminant concentrations are held constant and the flow rate is higher than that assumed, the required reactor will be larger as will the number of UV lamps thereby increasing electrical consumption. If the contaminant concentrations are held constant and the flow rate is lower than that assumed, the required reactor will be smaller as will the number of UV lamps thereby reducing electrical consumption. If the flow rate and/or contaminant concentrations are lower than that assumed, the piece of equipment specified in this FS can be operated at the proposed flow rate for a shorter period of time during the day, or the piece of equipment specified in this FS can be operated continuously while effectively shortening the residence time in the reactor by shutting down one or more UV lamp reaction chambers.

Re-injection costs are dependent on flow rate only. If the effluent flow from the treatment system is increased, a greater number of re-injection wells will be needed, increasing capital and operating costs. Likewise, if the effluent flow is decreased, fewer wells will be needed to re-inject the water into the aquifer and capital and operating costs will decrease.

6.3.3.9 State Acceptance. Since State representatives have not been provided with a formal opportunity to review the detailed analysis of the remedial actions, no formal comments are available for evaluation of this criterion.

6.3.3.10 Community Acceptance. Since the public has not been provided with a formal opportunity to review the detailed analysis of the remedial actions, no formal comments are available for evaluation of this criterion. It is anticipated that formal comments from the public will be provided during the 30-day public comment period for this FS report. These comments will then be addressed in the ROD and responsiveness summary.

6.3.4 Alternative T-4 - Precipitation/UV-Oxidation/Ion Exchange/Surface Water Discharge

6.3.4.1 Description. This alternative incorporates precipitation, UV-oxidation and ion exchange to treat contaminated groundwater to levels acceptable for surface water discharge. The flow diagram for this alternative is given in Figure 6-3. As in Alternative T-3, organic contaminants are removed using UV-oxidation (refer to description in Section 6.3.3.1). This alternative incorporates inorganics treatment as well to satisfy surface water discharge criteria. The Andco electrochemical precipitation process is proposed for this site because of its relatively low maintenance demands, low residuals production, and elimination of the storage of large quantities of chemicals on site. This process utilizes ferrous ions which coprecipitate heavy metals present in the groundwater. The ions are generated by passing a direct current through a cell containing carbon steel electrodes. Because calcium or ferric salt additives are not used to form a precipitate, the amount of sludge produced is reduced. Precipitates which form settle out in a clarifier, are pumped to a filter press, are dewatered and then disposed in the form of sludge. The sludge will be tested using the TCLP and disposed properly. Treated water is filtered through a GMF to remove any additional suspended solids prior to treatment with UV-oxidation. There is some question about the fate of explosives such as 2,4,6-TNT in the electrochemical environment generated by this system. This explosive could possibly be altered to form compounds which may be more difficult to oxidize. The formation of such compounds will be determined through treatability studies.

Precipitation is expected to achieve treatment of heavy metals and other inorganics to levels below the groundwater standards. Table 6-4 gives demonstrated performance treatment levels achieved by the Andco electrochemical process. The levels achieved through precipitation will approach surface water discharge criteria. However, metals such as cadmium, lead and zinc may not be removed to the levels required to meet remedial action objectives. Therefore, ion exchange will be implemented following the organics treatment as a polishing step.

After treatment through the UV-oxidation system described in Alternative T-3, the groundwater is filtered through a GMF unit. This filtration step removes precipitates which may have been formed as a result of the oxidation system. This step is necessary to avoid excessive buildup of solids in the ion exchange system which follows. It is also necessary that the treated groundwater be free of oxidants, since their presence affects the performance of the ion exchange system. Oxidant content is controlled through the careful monitoring of hydrogen peroxide and ozone dosages in the UV-oxidation process so that excessive amounts are not injected into the system.

Ion exchange is placed at the end of this system as organic contaminants must be eliminated to avoid interference with the plastic resin beads. The ion exchange system cannot be utilized without first treating the groundwater with a precipitation system. Due to the high levels of other metals which do not require treatment to meet discharge requirements (e.g., aluminum), the resin usage rate would be too high to permit the economical and practical use of this unit. An ion exchange system exchanges metals remaining in the groundwater, such as cadmium, iron and zinc, for less toxic cations such as hydrogen or sodium. In order to remove such metals, a strong acid cation resin is required (Corbitt, 1990). Until additional data are collected, it is not known at this time if an anion exchange system will be necessary. An anion exchanger step may be necessary to remove selected anions (such as cyanide) or to stabilize the pH of the effluent; however, it is not thought to be necessary and will not be considered at this time.

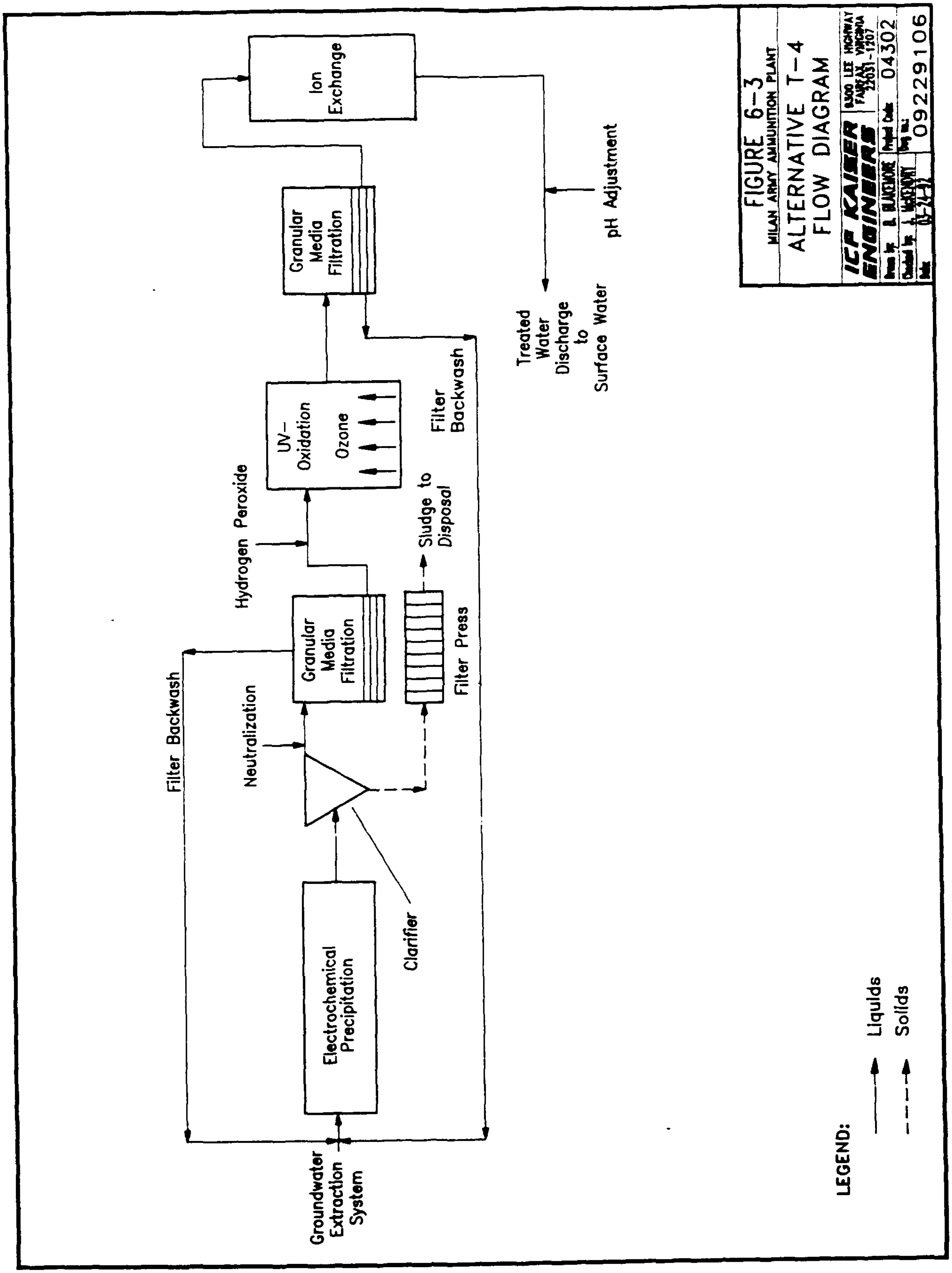


FIGURE 6-3
MILAN ARMY AMMUNITION PLANT
ALTERNATIVE T-4
FLOW DIAGRAM
ICF KAISER ENGINEERS
04302
09229106
Groundwater Extraction System
Electrochemical Precipitation
Clarifier
Neutralization
Granular Media Filtration
Filter Backwash
Filter Press
Sludge to Disposal
Hydrogen Peroxide
UV-Oxidation
Ozone
Granular Media Filtration
Filter Backwash
Ion Exchange
pH Adjustment
Treated Water Discharge to Surface Water
LEGEND:
Liquids
Solids

TABLE 6-4
HEAVY METAL LEVELS ACHIEVABLE THROUGH ELECTROCHEMICAL PRECIPITATION

Metal	Cadmium	Silver	Iron	Chromium	Vanadium	Aluminum	Arsenic
Influent Level mg/L	20.0	10.0	69.0	61.5	43.0	20.0	7.0
Effluent Level mg/L	0.002	<0.02	0.05	0.05	0.02	0.2	0.01

Source: Andco Environmental Processes Incorporated.

Once resins have been exhausted, one of two actions may be taken. Some vendors offer regeneration services. This service replaces the entire ion exchange unit with a new one, thereby avoiding downtime caused by regeneration cycles. Exhausted resin is then often taken to a metals recovery operation [illegible] regenerated for future use. To minimize the downtime, more than one unit is used so that one system may be changed while other units are treating the water; however, units must be frequently changed. Another option is to set up a number of permanent units which could occasionally be rinsed with a weak acid to remove the metals. This backwash could then be recycled back into the precipitation unit for further treatment. This process would prolong the life of the resin and reduce the frequency of resin change-out. The first option is considered in the costing of alternatives since it eliminates the need for chemical storage and provides ease in managing exhausted resins.

Treated groundwater is pumped to a nearby surface water body and discharged. Although an NPDES permit is not required, the substantive requirements of a permit must be met. Discharge to the Rutherford Fork is preferred over discharge to a nearby ditch because it is more likely to be unaffected by a large quantity of daily discharge and offers advantages due to a higher baseflow which provides greater mixing. A double-wall galvanized steel pipe will be used to transport treated water from the treatment site to the discharge point. The pipe will be heated using steam injectors to prevent freezing.

6.3.4.2 Overall Protection of Human Health and the Environment. This alternative will be designed to reduce the chemical concentrations in the groundwater to below the selected cleanup criteria, thus adequately protecting human health and the environment. Cleanup criteria are based on surface water ARARs or potential risk. When combined with an extraction alternative, active remediation of the contaminated groundwater will be provided, thus reducing future risk associated with the site. During the remediation activities, public health will be adequately protected through restriction of groundwater use and proper monitoring of potentially affected media.

6.3.4.3 Compliance with ARARs. It is assumed that this alternative will be operated in accordance with all Federal and Tennessee treatment facility requirements. It is also assumed that the chemical concentrations specified for groundwater treatment, whether they are statutory or risk based, are sufficiently low to also meet surface water discharge requirements. The treatment system itself will be designed to reduce chemical concentrations to below the specified target levels for each chemical present in the groundwater. Based on these assumptions and analyses, this alternative is expected to comply with all ARARs and TBCs related to the groundwater media.

6.3.4.4 Long-Term Effectiveness and Permanence. With proper design, the treatment processes incorporated into this alternative should be capable of providing long-term effectiveness and permanence. As described in Alternative T-3, the oxidizing ability of the UV-oxidation system is highly dependent on the amount of hydrogen peroxide and ozone injected into the system as well as the holding time. Because of this, the system possesses a flexibility capable of dealing with future contaminant fluctuations. Operating parameters for the Andco electrochemical precipitation process include pH and iron dosage. By optimizing these parameters, iron co-precipitation can be adjusted thereby controlling the precipitation of the inorganics of concern. If, for instance, greater levels of metals are observed in the future, the pH may be adjusted to accommodate specific metals of concern, since each metal precipitates at its own optimum pH. The dosage of ferrous ions may be adjusted to obtain similar control of selective metals precipitation. The ion exchange system may be adjusted by increasing the frequency of recycle so that the resin is able to accommodate increased levels of metals. Likewise, if a leased system is used, systems may be changed more or less frequently. Influent and effluent sampling will be implemented to monitor groundwater quality.

Residuals are generated from the precipitation system. A conservative estimate of approximately 110 gallons of dewatered sludge may be generated per day. This sludge will be analyzed by the TCLP

and properly disposed. It is no* expected to be hazardous due to the relatively low concentrations of metals in the groundwater.

Exhausted resin with the ion exchange unit will be claimed by the vendor and taken to a recycle plant where metals are recovered and used for other purposes. As described in Alternative T-3, treatment through UV-oxidation destroys contaminants and, therefore, generates no residuals requiring disposal. The granular media filtration system used for pretreatment prior to the ion exchange unit may occasionally need to be backflushed to the precipitation unit. Suspended solids which accumulate may be drained and disposed. The solids are not expected to be hazardous, since the levels of inorganics observed in the groundwater are relatively low, however, confirmatory analysis will be conducted to ensure that residuals are managed properly.

The actual effectiveness of this alternative for the O-Line Ponds area groundwater cannot be determined without treatability study testing to determine the chemical removal efficiencies and operating parameters of the precipitation and UV-oxidation equipment. Vendor information indicates that these systems are capable of meeting the treatment requirements. However, the effectiveness of the complete process will depend on more thorough engineering design, chemical analyses and treatability studies.

6.3.4.5 Reduction of Toxicity, Mobility or Volume. This alternative will address the principal threats posed by the organic and inorganic contaminants in the groundwater. If properly implemented, UV-oxidation will destroy the organic contaminants present in the groundwater. Therefore, the volume of the contaminants will be reduced. Assuming that full oxidation is achieved, contaminants are broken down into harmless products: carbon dioxide, nitrogen, water and salts. Since the molecular bonds which once held the organics together are broken, this process is not reversible. Therefore, the toxicity of the organic contaminants is eliminated.

Precipitation and ion exchange treatment will remove metals from the groundwater, thereby reducing the volume of these constituents in the groundwater media. By concentrating the metals within a sludge, the overall volume is also reduced. The toxicity of these contaminants, although reduced in the groundwater, remains within the residuals. These residuals will be tested by the TCLP and disposed properly; this may involve stabilization, recovery or other processes that reduce of the mobility of these contaminants thereby reducing toxicity at the point of disposal. The specific design of this system is dependent on modeling and aquifer testing results.

6.3.4.6 Short-Term Effectiveness. Construction of the extraction system, treatment facility and discharge system will be completed with standard construction equipment and will not entail additional risks to workers beyond those risks inherent in construction projects. Likewise, employees and the community located within the vicinity of the site will not be adversely affected by the construction of the treatment facility.

Because of the rather large size of the treatment system, its design and construction may take 12-24 months. This time estimate includes the treatment system design and review, preparation of bid packages, selection of contractors and equipment suppliers, installation, and start-up.

6.3.4.7 Implementability. The treatment processes combined in this alternative are commonly used in water and wastewater treatment systems; basic designs are proven and commercially available. Although commercially available, UV-oxidation systems are produced by only a few vendors, each with its own designs which differ greatly from one another. In addition, Andco's electrochemical precipitation process is proprietary. Because of the variables involved in the UV-oxidation and precipitation systems, the units have the flexibility to be readily adjusted if necessary in the future. Electricity and water are required to run the systems within this alternative, and both are available at the site. An operator will be required for approximately one-eight hour shift per day to perform inspections of the UV-oxidation system,

monitor the precipitation and ion exchange systems and clean out residuals from the filter press (see Appendix C).

Due to the long period of treatment anticipated, extensive administrative oversight will be required to ensure the proper operation and maintenance and overall performance of the preferred alternative. Long-term monitoring of influent and effluent concentrations, residual characteristics, and the effectiveness of the alternative will be required. Because only one operable unit at the site is addressed by this action, five year reviews will also be required as part of the long-term monitoring program. Although complicated and time consuming, the tasks associated with coordinating the management of this alternative are feasible and implementable.

6.3.4.8 Cost. A summary of the costs for this alternative are given in Table 6-5. The total capital cost for the treatment system for Alternative T-4 is $2,353,000. A replaceable ion exchange system is utilized in this cost estimate because of the ease in managing spent resin. Therefore, no capital costs are incurred through the use of this ion exchange system. Additional capital costs include $206,000 for site preparation and $637,000 for the installation of a surface water discharge system. The total present worth of this alternative is estimated to be approximately $47,397,000 (30 years, 5% discount rate), including capital costs of $6,030,000 and annual O&M expenditures of $2,691,000. These costs are preliminary and are subject to change depending on modeling, aquifer testing and treatability tests. Initial costs are based on vendor information and generic unit costs. Cost calculation sheets are provided in Appendix C.

The capital costs for the electrochemical precipitation unit will be affected by the selected flow rate. If the flow rate is lower than that assumed and the inlet contaminant concentrations are held constant, a smaller unit (e.g., smaller clarification area) can be designed. Similarly, if the flow rate is higher than that assumed and the inlet contaminant concentrations are held constant, a larger unit can be designed. Although the size of the unit will affect the capital cost of the unit, cost versus flow rate is not a linear function due to economies of scale. For the electrochemical precipitation process, flow rate is expected to have a greater effect on equipment size than inlet contaminant concentrations since the size of the equipment is mainly determined based on the rate of flocculent settling rather than on a chemical reaction. In general, polymers can be added to the groundwater to enhance settling as necessary to respond to contaminant concentration variations. However, the sizing of ancillary equipment such as the filter press is highly dependent upon the contaminant loading in the groundwater and the groundwater flow rate.

The most significant operating costs for electrochemical precipitation are electrical and iron consumption. If either the flow rate or the inlet contaminant concentrations are higher than that assumed, the electrical consumption and iron dosage will increase. If either the flow rate or the inlet contaminant concentrations are lower than that assumed, the electric consumption and iron dosage will decrease. Electrical consumption and iron dosage are more linearly related to flow rate than to inlet contaminant concentrations. The optimum dosage of iron would have to be determined through treatability testing should the inlet contaminant concentrations change significantly. Sludge disposal is also a significant operating cost; sludge volume is directly related to the contaminant loading in the groundwater and the groundwater flow rate.

Capital and operating costs for the UV-oxidation system is dependent on flow rate and inlet contaminant concentrations as discussed in Alternative T-3.

The capital and operating costs of the ion exchange unit will increase with increased flow rate. If the inlet contaminant concentrations are kept constant and the flow rate is higher than initially predicted, a larger exchange unit is necessary to accommodate the additional flow. In addition,

TABLE 6-5 SUMMARY OF COSTS FOR ALTERNATIVE I-4: PRECIPITATION/ UV-OXIDATION/ ION EXCHANGE/ SW DISCHARGE

NOTES AND ASSUMPTIONS

(a) - For controlling access to contaminated areas, restricting future property use, and restricting the drilling of new drinking water wells.
(b) - To increase public awareness of hazards through press releases, presentations, and posting of signs.
(c) - Costs include the annual salary of one program oversight manager for the groundwater treatment program. Costs do not include government oversight of this task.
(d) - 30 ft x 40 ft staging area of 8" deep gravel.
(e) - Includes a 75 ft x 100 ft prefabricated steel building, 6" concrete base, insulation, electrical wiring, and plumbing.
(f) - Lighting consists of 25 8' fluorescent lights.
(g) - Includes electrochemical precipitation system consisting of a reactor, a clarifier, a granular media filtration unit, a filter press, assorted pumps,tanks and controls. Operating costs of $0.25/ 1000gal wastewater include power and maintenance. The amount of sludge removed is estimated at 15 cubic feet/day @ $180/55 gal drum.
(h) - Includes 3 5000gal contactors, 4 reactors, and ozone generator. Operating costs include hydrogen peroxide, ozone, and electrical costs.
(i) - Includes 3 vessel multi-media filter skid with pumps, influent and effluent tanks. Operating costs of $0.20/ 1000gal wastewater.
(j) - Ion exchange unit is purchased on a lease basis. Annual costs include the replacement of ion exchange unit, maintenance of equipment, recycling of regenerative waste, and transportation of waste.
(k) - Part-time system operator is assumed to cost $20/hr and is used approximately 1 8hr shift per day. Two months operator training has been included as a capital cost.
(l) - Sixty effluent samples will be taken per year and analyzed for TAL/TCL, explosives, and cyanide. The analytical costs are $2000 per sample. *The residual samples (24/year) will be tested for TCLP metals and VOCs,* corrosivity, ignitability and reactivity at a cost of $700 per sample. Capital costs include 100 additional samples for TAL/TCL, explosives and cyanide which will be needed during system start-up.
(m) - The cost for well sampling is $2260 per sampling event. Six (6) wells are proposed. The analytical costs are $2000 per sample, tested for TAL/TCL, explosives and cyanide.
(n) - The cost for surface water sampling is $2260 per sampling event. Six locations are proposed to be monitored quarterly. Surface water will be tested for TAL/TCL, explosives and cyanide at a cost of $2000 per sample.
(o) - Cost includes permit application process and/or coordination with state/federal officials regarding discharge of treated water.

operating costs will increase, since a larger quantity of resin will need replacement after exhaustion. If the flow rate is less than that predicted, a smaller unit could be designed and less resin would need replacement. Capital costs versus flow rate is not a linear function due to economies of scale.

Operating costs for the ion exchange system will also fluctuate with inlet contaminant concentrations. If the design flow rate is sustained and inlet concentrations increase, it will be necessary to replace exchange beds more frequently. Likewise, if influent concentrations decrease, exchange units will have a longer lifetime and operating costs will decrease due to fewer resin replacements. Since ion exchange is used after primary inorganics and organics treatment, fluctuations in inlet contaminant concentrations are less likely to occur at this point in the treatment process.

Capital and operating costs associated with surface water discharge are dependent on flow rate only. If the design flow rate is lower than that predicted, smaller diameter (i.e. lower cost) piping may be used and lower heating costs will be incurred. Similarly, larger diameter (i.e. higher cost) piping and higher heating costs will be experienced for a discharge system capable of carrying a larger flow rate.

6.3.4.9 State Acceptance. Since State representatives have not been provided with a formal opportunity to review the detailed analysis of the remedial actions, no formal comments are available for evaluation of this criterion.

6.3.4.10 Community Acceptance. Since the public has not been provided with a formal opportunity to review the detailed analysis of the remedial actions, no formal comments are available for evaluation of this criterion. It is anticipated that formal comments from the public will be provided during the 30-day public comment period for this FS report. These comments will then be addressed in the ROD and responsiveness summary.

6.3.5 Alternative T-5 - Precipitation/GAC/Re-injection

6.3.5.1 Description. This alternative incorporates precipitation, GMF and GAC to treat groundwater to levels acceptable for groundwater re-injection. The flow diagram for this alternative is given in Figure 6-4. As explained in Alternative T-4, precipitation is expected to achieve heavy metals removal below the groundwater standards. Pretreatment of inorganics is vital to the efficient use of GAC for groundwater treatment. Without pretreatment for removal of inorganic constituents, heavy metals may be adsorbed and reduce the removal efficiency of the GAC system. Since a large amount of carbon is necessary to remove the organics present, any hindrance of the carbon's ability to adsorb additional organics would be detrimental to the overall efficiency of the system. Therefore, the electrochemical precipitation unit which incorporates clarification and filtration steps is implemented prior to treatment with GAC.

The GAC unit proposed for a 500 gpm system consists of 2 to 3 carbon units connected in series. Each unit is capable of holding approximately 20,000 lbs of virgin granular activated carbon. Loading data for the organic contaminants of concern is not readily available. Although previous treatability studies conducted elsewhere have demonstrated removal of explosives below detection limits, the influent level of explosives was often not as high as those observed at O-Line Ponds (Chemical Processing, 1983). Therefore, the loading rate of the carbon was estimated by vendors for the purposes of approximating the carbon usage. Carbon usage estimates ranged from 440 lbs/day to 1656 lbs/day. The variation in estimates comes from the different assumptions made in calculating usage rates because of insufficient data for certain explosives such as HMX and RDX. GAC is a proven technology for these contaminants; however the actual carbon usage rate must be determined during the treatability studies. For purposes of cost estimating, the highest quoted carbon usage rate (1656 lbs/day) was assumed. All exhausted GAC may be disposed through Solvent Recovery Corporation, a company who presently accepts the GAC used at the PWTFs at MAAP. Because the carbon is used as fuel, acceptance of the GAC and the costs

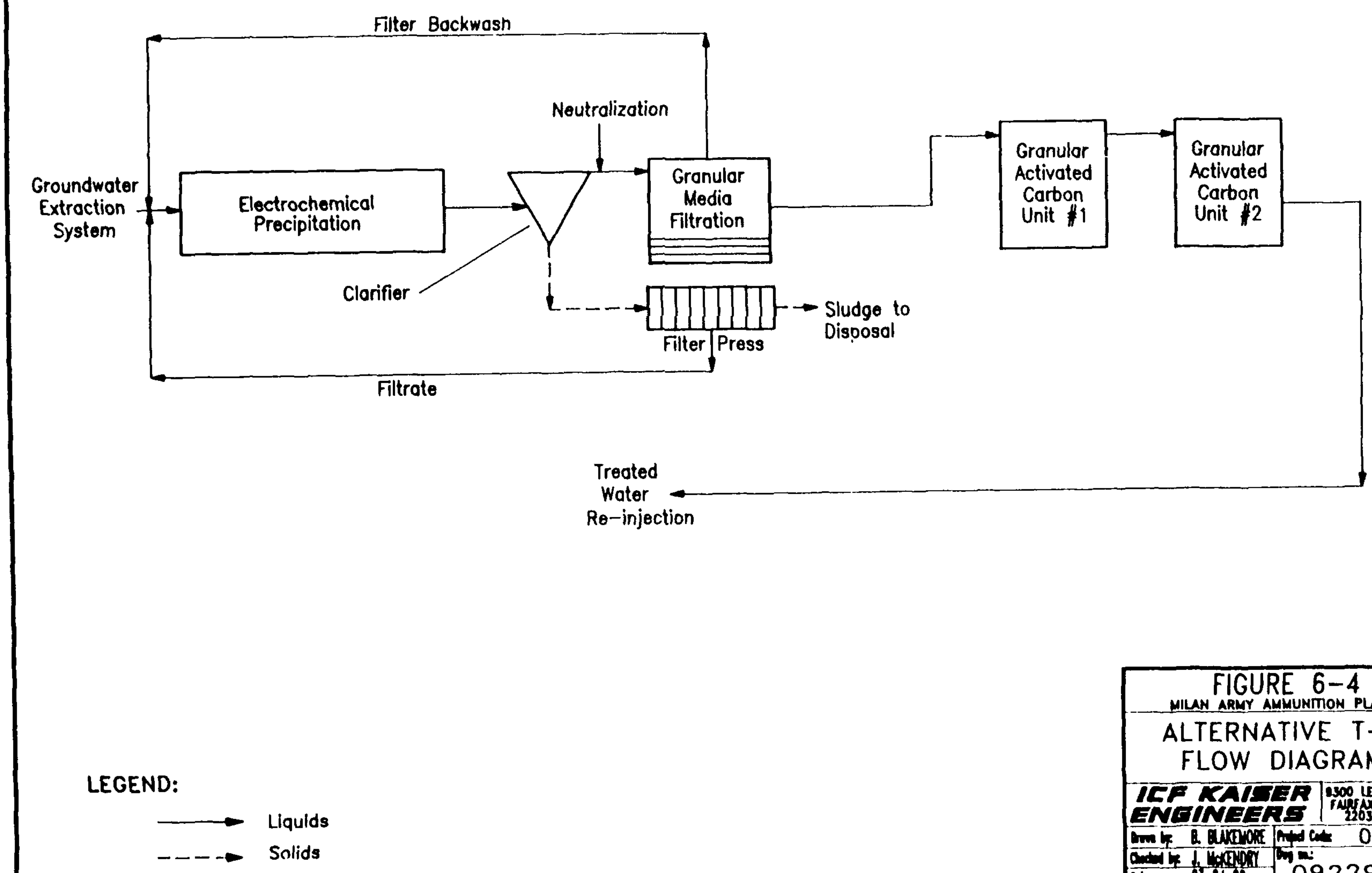


FIGURE 6-4
MILAN ARMY AMMUNITION PLANT
ALTERNATIVE T-5
FLOW DIAGRAM

ICF KAISER ENGINEERS
9300 LEE HIGHWAY FAIRFAX, VIRGINIA 22031-1207

Drawn by:	B. BLAKEMORE	Project Code:	04302
Checked by:	J. McKENDRY	Dwg no.:	09229107
Date:	03-24-92		

for disposal a e based on the Btu content of the carbon. The exhausted carbon from the PWTF is disposed through a high temperature incineration process operated by this company. After treatment at temperatures around 3000° F, the spent carbon is used in a cement-making process.

Treated water is re-injected either upgradient or downgradient of the extraction system as described in Alternative T-3.

6.3.5.2 Overall Protection of Human Health and the Environment. This alternative will be designed to reduce the chemical concentrations in the groundwater to below the selected cleanup criteria, thus adequately protecting human health and the environment. Clean-up criteria are based on groundwater ARARs and TBCs. When combined with an extraction system, active remediation of the contaminated groundwater will be provided, thus reducing future risk associated with the site. During the remediation activities, public health will be adequately protected through restriction of groundwater use and proper monitoring of potentially affected media.

6.3.5.3 Compliance with ARARs. It is assumed that this alternative will be operated in accordance with all Federal and Tennessee treatment facility requirements. It is also assumed that the chemical concentrations specified for groundwater treatment, whether they are statutory or risk based, are sufficiently low to also meet re-injection (groundwater) discharge requirements. The treatment system itself will be designed to reduce chemical concentrations to below the specified target levels for each chemical present in the groundwater. Based on these assumptions and analyses, this alternative is expected to comply with all ARARs and TBCs related to the groundwater media.

6.3.5.4 Long-Term Effectiveness and Permanence. Several variables incorporated into the precipitation and GAC treatment systems allow for flexibility which may ensure long-term effectiveness and permanence. Operating parameters for the Andco electrochemical precipitation process include pH and ferrous ion dosage. Optimization of these parameters allows for adjustment of iron co-precipitation which in turn controls the precipitation of the inorganics of concern.

The performance of GAC is dependent on the groundwater contact time with the carbon, the type of carbon used, the size of the carbon particle and the solubility of the organics in water. Most of these parameters must be determined from treatability study data. However, periodic influent and effluent sampling will allow accurate predictions of the various chemical breakthrough times and associated carbon exhaustion rates and, therefore, allow for adjustment in carbon bed life if the level of groundwater contaminants fluctuates. Two carbon beds are used in series to ensure that water which does not meet chemical-specific ARARs is not discharged if the first carbon bed breaks through.

One disadvantage of this alternative is the large amount of residuals (spent carbon) which will be generated. Estimates of carbon usage range between 440 lbs/day and 1656 lbs/day for a 500 gpm system. Although the actual usage rate will have to be determined based on treatability study data, this process could generate between 160,600 and 604,440 lbs of exhausted carbon per year. Due to the nature of the organic contaminants which adsorb to the carbon, this carbon will have to be tested and disposed since regeneration may not be possible. This type of waste is presently generated at the PWTF at MAAP.

Residual sludge from the precipitation unit will also be generated. A conservative estimate of approximately 110 gallons/day of sludge may be generated. This sludge will be tested by the TCLP for proper disposal.

The actual effectiveness of this alternative for the O-Line Ponds area groundwater cannot be determined without treatability study testing to determine the above-mentioned parameters for the

precipitation and GAC units. The determination of parameters such as carbon. contact time, and the carbon loading is vitally important to the effectiveness of the system.

6.3.5.5 Reduction of Toxicity, Mobility or Volume. This alternative will address the principle threats posed by the organic and inorganic contaminants in the groundwater. Because observed levels of inorganics are not above groundwater discharge levels, their removal may only be dependent on pretreatment requirements for the subsequent GAC treatment system.

The sludge produced from the precipitation system will require analytical testing and proper disposal. Large quantities of sludge are not expected to be generated; and, based on the levels of inorganics in the groundwater, the sludge is not expected to be hazardous. GAC will adsorb the organic contaminants present in the groundwater. Assuming that the proper GAC design is implemented, contaminants are transferred to the carbon, thus reducing their toxicity and volume in the groundwater medium. However, organics are not destroyed and require proper disposal to permanently reduce the toxicity and volume of these contaminants. Based on preliminary predictions, a large volume of spent carbon will be generated. A more accurate estimate of the quantity of spent carbon generated cannot be obtained until treatability studies are conducted. The mobility of the contaminants in the groundwater is reduced through the effective implementation of an extraction system. The specific design of this system is dependent on modeling and aquifer testing results.

6.3.5.6 Short-Term Effectiveness. Construction of the extraction system, treatment facility and discharge system will be completed with standard construction equipment and will entail no additional risks to workers beyond those risks inherent in construction projects. Likewise, employees and the community located within the vicinity of the site will be unaffected by the construction of the treatment facility.

Because of the rather large size of the treatment system, its design and construction may take 12-24 months. This time estimate includes the treatment system design and review, preparation of bid packages, selection of contractors and equipment suppliers, installation, and start-up.

6.3.5.7 Implementability. The treatment processes combined in this alternative are commonly used in water and wastewater treatment processes, are proven, and commercially available. However, Andco's electrochemical precipitation process is proprietary. The treatment component operating parameters can be varied to ensure that groundwater is effectively treated even if future groundwater quality varies. Electricity is required to run this system and is available at the site. Approximately one-eight hour shift per day will be required for operator oversight of this treatment system.

Due to the long period of treatment anticipated, extensive administrative oversight will be required to ensure the proper operation and maintenance and overall performance of the preferred alternative. Long-term monitoring of influent and effluent concentrations, residual characteristics, and the effectiveness of the alternative will be required. Five year reviews will also be required as part of the long-term monitoring program. Although complicated and time consuming, the tasks associated with coordinating the management of this alternative are feasible and implementable.

6.3.5.8 Cost. A summary of the costs for this alternative are given in Table 6-6. The total capital cost for the treatment system for Alternative T-5 is $1,023,000. Additional capital costs include $206,000 for site preparation and $451,000 for re-injection. The total present worth of this alternative is estimated to be approximately $33,567,000 (30 years, 5% discount rate), including capital costs of $3,376,000 and annual O&M expenditures of $1,964,000. These costs are preliminary and are subject to change depending on modeling, aquifer testing and treatability tests. Initial costs are based on vendor information and generic unit costs. Cost calculation sheets are provided in Appendix C.

TABLE 6-6 SUMMARY OF COSTS FOR ALTERNATIVE T-5: PRECIPITATION/ GAC/ RE-INJECTION

ITEM	QUANTITY	CAPITAL COST	ANNUAL O & M COST	Present Worth of Annual Costs 30 years, 5%	Present Worth of Annual Costs 30 years, 10%
I. Administrative Actions					
1. Institutional Restrictions/Emergency Provisions (a)		$15,000			
2. Public Education Program (b)		$20,000			
3. Program Oversight (c)			$75,000	$1,153,000	$707,000
Subtotal:		$35,000	$75,000	$1,153,000	$707,000
II. GENERAL ACTIONS/SITE PREPARATION					
1. Parking/Staging Area (d)	1200 sq ft	$1,000			
2. Treatment System Building Construction (e)	7500 sq ft	$150,000			
3. Building Lighting and Heating (f)		$35,000	$7,000	$108,000	$66,000
4. Contractor Mobilization/ Demobilization		$20,000			
Subtotal:		$206,000	$7,000	$108,000	$66,000
III. GROUNDWATER TREATMENT SYSTEM					
1. Pre-treatment System (Precipitation) (g)		$850,000	$200,000	$3,074,000	$1,885,000
2. Granular Activated Carbon (GAC) Adsorption Unit (h)		$165,000	$956,000	$14,696,000	$9,012,000
3. Part-time System Operator (i)	2180 hrs/yr	$8,000	$44,000	$676,000	$415,000
Subtotal:		$1,023,000	$1,200,000	$18,446,000	$11,312,000
IV. RE-INJECTION SYSTEM					
1. Injection Wells	3 wells	$99,000	$5,000	$77,000	$47,000
2. Horizontal Pumps	3 pumps	$11,000	$26,000	$400,000	$245,000
3. Discharge Piping	4450 ft	$316,000			
4. System Controls		$25,000			
Subtotal:		$451,000	$31,000	$477,000	$292,000
V. LONG-TERM MONITORING & REVIEW					
1. Weekly Effluent & Monthly Residuals Monitoring (j)		$200,000	$121,000	$1,860,000	$1,141,000
2. Quarterly [illegible]ndwater Monitoring and Reporting (k)	6 wells		$67,000	$1,030,000	$632,000
3. Quarterly [illegible]ace Water Monitoring & Reporting (l)			$67,000	$1,030,000	$632,000
4. Five-Year R[illegible]views ($15,000 ea)	6 reports		$3,000	$46,000	$28,000
Subtotal:		$200,000	$258,000	$3,966,000	$2,433,000
SUBTOTAL (I, II, III, IV and V)		$1,915,000	$1,571,000	$24,150,000	$14,81[illegible]
VI. ADDITIONAL SYSTEM COSTS					
1. Health and Safety 10% of Capit[illegible] subtotal		$192,000			
2. Bid Contingency 15% of Capital subtotal		$287,000			
3. Scope Contingency 15% of Capital subtotal		$287,000			
25% of Annual subtotal			$393,000	$6,041,000	$3,705,000
Subtotal:		$766,000	$393,000	$6,041,000	$3,705,000
CONSTRUCTION SUBTOTAL (I, II, III, IV, V AND VI)		$2,681,000	$1,964,000	$30,191,000	$18,515,000
VII. IMPLEMENTATION COST					
1. Eng. Services During Construction 15% of system subtotal		$402,000			
2. Engineering & Design 10% of system subtotal		$268,000			
3. Permitting/ Coordination (m)		$25,000			
Subtotal:		$695,000			
A. TOTAL CAPITAL COSTS		$3,376,000			
B. TOTAL ANNUAL COSTS			$1,964,000		
C. TOTAL PRESENT WORTH OF ANNUAL COSTS				$30,191,000	$18,515,000
TOTAL PRESENT WORTH OF CAPITAL AND ANNUAL COSTS (A + C)				$33,567,000	$21,891,000

TABLE 6 6 SUMMARY OF COSTS FOR ALTERNATIVE I-5: PRECIPITATION/ GAC/ RE-INJECTION

NOTES AND ASSUMPTIONS

(a) - For controlling access to contaminated areas, restricting future property use, and restricting the drilling of new drinking water wells.
(b) - To increase public awareness of hazards through press releases, presentations, and posting of signs.
(c) - Costs include the annual salary of one program oversight manager for the groundwater treatment program. Costs do not include government oversight of this task.
(d) - 30 ft x 40 ft staging area of 8" deep gravel.
(e) - Includes a 75 ft x 100 ft prefabricated steel building, 6" concrete base, insulation, electrical wiring, and plumbing.
(f) - Lighting consists of 25 8' fluorescent lights.
(g) - Includes electrochemical precipitation system consisting of a reactor, a clarifier, a granular media filtration unit, a filter press, assorted pumps and tanks. Operating costs of $0.25/ 1000gal wastewater include power and maintenance. The amount of sludge removed is estimated at 15 cubic feet/day @ $180/55 gal drum.
(h) - Includes 2 20,000lb absorbers connected in series. Annual costs include delivery and cost of activated carbon which must be replaced 15 times annually. Estimated carbon usage is approximately 1656 lbs/day.
(i) - Part-time system operator is assumed to cost $20/hr and is used approximately 1 8hr shift per day. Two months operator training has been included as a capital cost.
(j) - Sixty effluent samples will be taken per year and analyzed for TAL/TCL, explosives, and cyanide. The analytical costs are $2000 per sample. The residual samples (24/year) will be tested for TCLP metals and VOCs, corrosivity, ignitability and reactivity at a cost of $700 per sample. Capital costs include 100 additional samples for TAL/TCL, explosives and cyanide which will be needed during system start-up.
(k) - The cost for well sampling is $2260 per sampling event. Six (6) wells are proposed. The analytical costs are $2000 per sample, tested for TAL/TCL, explosives and cyanide.
(l) - The cost for surface water sampling is $2260 per sampling event. Six locations are proposed to be monitored quarterly. Surface water will be tested for TAL/TCL, explosives and cyanide at a cost of $2000 per sample.
(m) - Cost includes permit application process and/or coordination with state/federal officials regarding discharge of treated water.

The cost sensitivity of the electrochemical precipitation unit is described in Alternative T-4.

GAC units are designed to provide an adequate contact time given a maximum flow rate. If the flow rate is lower than that assumed and the contaminant concentrations are held constant, a smaller piece of equipment can be specified. The depth of the carbon bed (i.e., the contact time) will not be reduced; however, the cross-sectional area of the unit would be reduced. If the flow rate is higher than that assumed and the contaminant concentrations are held constant, a larger piece of equipment (i.e., larger cross-sectional area to accommodate the higher flow rate) or a number of small adsorption units in parallel can be designed. Again, the depth of the carbon bed(s) will be held constant. As with the UV-oxidation unit, the cost of the GAC unit will vary with flow rate; however, cost versus flow rate is not a linear function due to economies of scale. The carbon usage rate is also dependent upon the flow rate. If the flow rate is lower than that assumed and the inlet contaminant concentrations are held constant, the carbon usage rate will be lower because the unit is smaller (i.e., holds less carbon) even though the carbon bed life (i.e., time to contaminant breakthrough) does not change. If the flow rate is higher than that assumed and the inlet contaminant concentrations are held constant, the carbon usage rate will be higher because the unit is larger (i.e., holds more carbon) even though the carbon bed life does not change.

If the inlet contaminant concentrations are either higher or lower than that assumed and the flow rate is held constant, the size of the carbon adsorption unit will not be affected since sizing is mainly determined based on flow rate and required contact time to allow contaminants to adsorb. The only effect that a change in inlet contaminant concentrations will have on the carbon adsorption unit is on operating costs (i.e., purchase of activated carbon and regeneration/disposal of spent carbon). That is, if the inlet concentrations are lower than that assumed, the carbon adsorption bed will have a longer life (i.e., time to contaminant breakthrough) and will have to be changed out less frequently; and if the inlet contaminant concentrations are higher than that assumed, the carbon adsorption bed will have a shorter life and will have to be changed out more frequently. The relationship between inlet contaminant concentrations and time to breakthrough is not a linear one.

The effects of increased or decreased flow rate on re-injection costs are described in Alternative T-3.

6.3.5.9 State Acceptance. Since State representatives have not been provided with a formal opportunity to review the detailed analysis of the remedial actions, no formal comments are available for evaluation of this criterion.

6.3.5.10 Community Acceptance. Since the public has not been provided with a formal opportunity to review the detailed analysis of the remedial actions, no formal comments are available for evaluation of this criterion. It is anticipated that formal comments from the public will be provided during the 30-day public comment period for this FS report. These comments will then be addressed in the ROD and responsiveness summary.

6.3.6 Alternative T-6 - Precipitation/GAC/Ion Exchange/Surface Water Discharge

6.3.6.1 Description. This alternative incorporates precipitation, GAC and ion exchange to treat groundwater to levels acceptable for surface water discharge. The flow diagram for this alternative is given in Figure 6-5. The first part of this alternative, precipitation and GAC, is identical to the process described in Alternative T-5. The ion exchange, system described in Alternative T-4, is implemented after the GAC system to reduce levels of metals such as cadmium, zinc and lead to surface water discharge criteria. Treated water is pumped either to a nearby ditch or the Rutherford Fork of the Obion River.

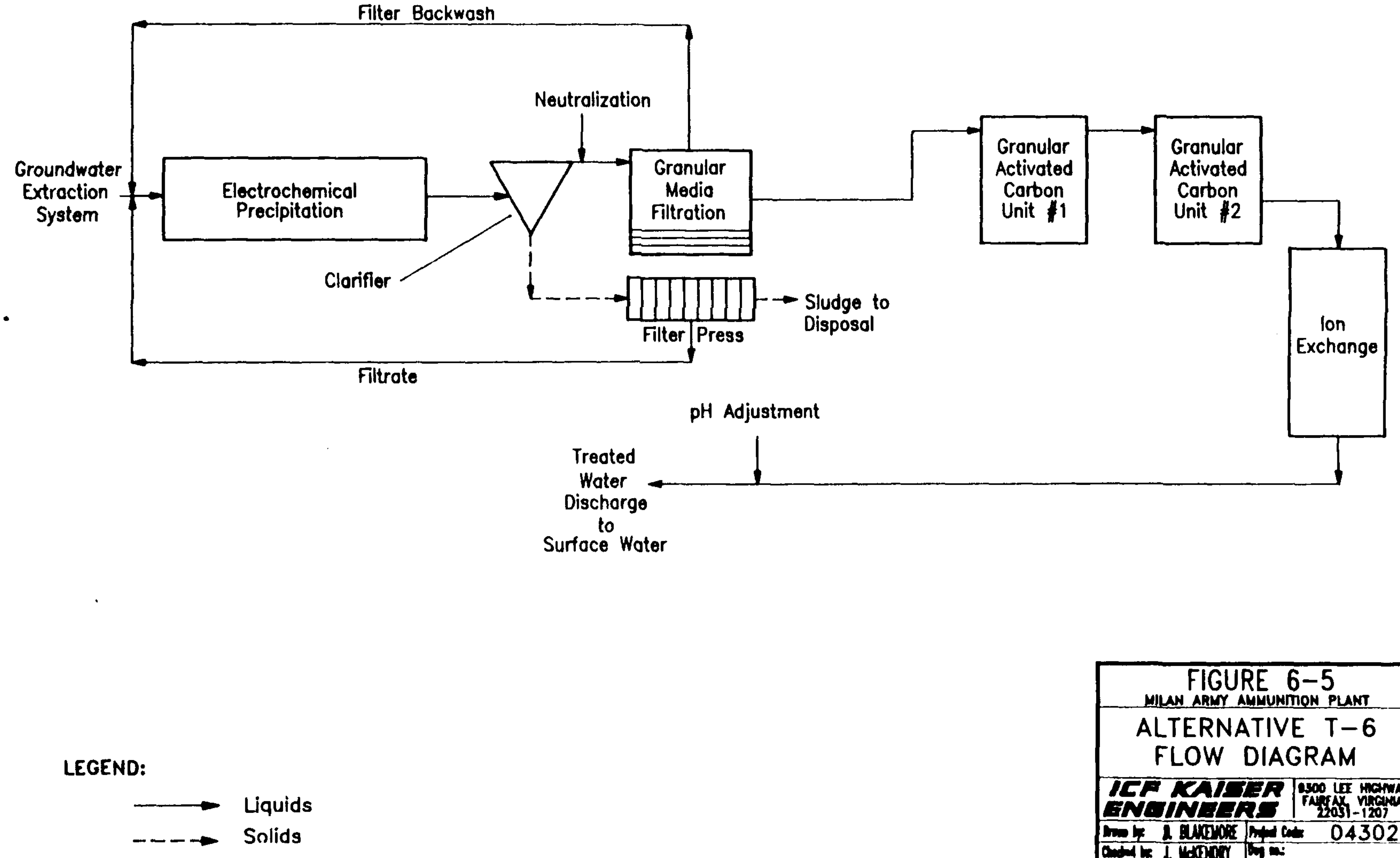


FIGURE 6–5
MILAN ARMY AMMUNITION PLANT

ALTERNATIVE T–6
FLOW DIAGRAM

ICF KAISER ENGINEERS
9300 LEE HIGHWAY FAIRFAX, VIRGINIA 22031-1207

Drawn by: B. BLAKEMORE | Project Code: 04302
Checked by: J. McKENDRY | Dwg no.: 09229108
Date: 03-24-92

6.3.6.2 Overall Protection of Human Health and the Environment. This alternative will be designed to reduce the chemical concentrations in the groundwater to below the selected cleanup criteria, thus adequately protecting human health and the environment. Cleanup criteria are based on surface water ARARs or potential risk. When combined with an extraction system, active remediation of the contaminated groundwater will be provided, thus reducing future risk associated with the site. During the remediation activities, public health will be adequately protected through restriction of groundwater use and proper monitoring of potentially affected media.

6.3.6.3 Compliance with ARARs. It is assumed that this alternative will be operated in accordance with all Federal and Tennessee treatment facility requirements. It is also assumed that the chemical concentrations specified for groundwater treatment, whether they are statutory or risk based, are sufficiently low to also meet surface water discharge requirements. The treatment system itself will be designed to reduce chemical concentrations to below the specified target levels for each chemical present in the groundwater. Based on these assumptions and analyses, this alternative is expected to comply with all ARARs and TBCs related to the groundwater media.

6.3.6.4 Long-Term Effectiveness and Permanence. As in Alternative T-5, several variables incorporated into the precipitation and GAC treatment systems allow for flexibility which may ensure long-term effectiveness and permanence. Periodic influent and effluent sampling will allow accurate predictions of pH or ferrous ion dosage for the precipitation unit and of the various chemical breakthrough times and associated carbon exhaustion rates for the GAC unit, thereby allowing for adjustment if the levels of groundwater contaminants fluctuates. Ion exchange units may also accommodate contaminant concentration fluctuations by more or less frequent replacement.

As noted in Alternative T-5, one major disadvantage of this system is the generation of large quantities of spent carbon. It is likely that this carbon cannot be regenerated and must be treated through an incineration process such as the off-site treatment presently used by MAAP. In addition, residual sludge from the precipitation unit will also be generated. These residuals will be tested by the TCLP and properly stabilized and disposed. Ion exchange resins will be accepted by the vendor for the purposes of recovering the metals.

The actual effectiveness of this alternative cannot be determined without treatability study testing to determine the above-mentioned parameters for the precipitation, GAC, and ion exchange units.

6.3.6.5 Reduction of Toxicity, Mobility or Volume. This alternative will address the principal threats posed by the organic and inorganic contaminants in the groundwater. Because observed levels of inorganics are above surface water discharge levels, their removal is necessary prior to discharge.

As in Alternative T-5, the sludge produced from the precipitation system and the spent carbon will require analytical testing and disposal. Precipitation removes inorganics present in the groundwater, and GAC adsorbs the organic contaminants present in the groundwater. These two processes will reduce the volume and toxicity of the contaminants in the groundwater. The permanent reduction of the toxicity and volume of these contaminants in the environment is dependent on the proper disposal of the residuals. Exhausted ion exchange resin will be accepted by the vendor and taken to a recycling plant where metals are recovered for other uses. The mobility of the contaminants is reduced through the effective implementation of an extraction system. The specific design of this system is dependent on modeling and aquifer testing results.

6.3.6.6 Short-Term Effectiveness. Construction of the extraction system, treatment facility, and discharge system will be completed with standard construction equipment and will entail no additional risks to workers beyond those risks inherent in construction projects. Employees and the community located within the vicinity of the site will be unaffected by the construction of the treatment facility.

Because of the rather large size of the treatment system, its design and construction may take 12-24 months. This time estimate includes the treatment system design and review, preparation of bid packages, selection of contractors and equipment suppliers, installation, and start-up.

6.3.6.7 Implementability. The treatment processes combined in this alternative are commonly used in water and wastewater treatment processes, are proven, and commercially available. However, Andco's electrochemical precipitation process is proprietary. The treatment component operating parameters can be varied to ensure that groundwater is effectively treated even if future groundwater quality varies. Electricity is required to run these systems and is available at the site. Approximately one-eight hour shift per day will be required for operator oversight of this treatment system (see Appendix C).

Due to the long period of treatment anticipated, extensive administrative oversight will be required to ensure the proper operation and maintenance and overall performance of the preferred alternative. Long-term monitoring of influent and effluent concentrations, residual characteristics, and the effectiveness of the alternative will be required. Five year reviews will also be required as part of the long-term monitoring program. Although complicated and time consuming, the tasks associated with coordinating the management of this alternative are feasible and implementable.

6.3.6.8 Cost. A summary of the costs for this alternative are given in Table 6-7. The total capital costs for the treatment system for Alternative T-6 is $1,023,000. Additional capital costs include $206,000 for site preparation and $637,000 for the installation of a surface water discharge system. The total present worth of this alternative is estimated to be approximately $52,324,000 (30 years, 5% discount rate), including capital costs of $3,701,000 and annual O&M expenditures of $3,163,000. These costs are preliminary and are subject to change depending on modeling, aquifer testing, and treatability tests. Initial costs are based on vendor information, and generic unit costs. Cost calculation sheets are provided in Appendix C.

A description of cost sensitivity with respect to flow rate and inlet contaminant concentrations for the components of this alternative is given in Alternatives T-3, T-4 and T-5.

6.3.6.9 State Acceptance. Since State representatives have not been provided with a formal opportunity to review the detailed analysis of the remedial actions, no formal comments are available for evaluation of this criterion.

6.3.6.10 Community Acceptance. Since the public has not been provided with a formal opportunity to review the detailed analysis of the remedial actions, no formal comments are available for evaluation of this criterion. It is anticipated that formal comments from the public will be provided during the 30-day public comment period for this FS report. These comments will then be addressed in the ROD and responsiveness summary.

6.3.7 Alternative T-7 - Precipitation/UV-Oxidation/GAC/Re-Injection

6.3.7.1 Description. In this alternative, shown schematically in Figure 6-6, UV-oxidation and GAC are used in series. Groundwater is first pretreated using the precipitation system described in Alternative T-4. Organics then undergo preliminary treatment using UV-oxidation (see Alternative T-3). GAC (see Alternative T-5) is then implemented as a polishing step to reduce organic levels to below health advisory levels. The specific treatment goals of the UV-oxidation system is dependent on the economic benefits gained in optimizing operating conditions of the system. If, for example, it is demonstrated during treatability tests that a certain constituent is rate limiting or cannot economically be reduced to its treatment goal, it may be more efficient to complete organics treatment using GAC, rather than increase operational costs of the UV-oxidation system to meet the treatment goal set for the constituent. The bulk of the explosive-contaminants are expected to be destroyed

TABLE 6-7 SUMMARY OF COSTS FOR ALTERNATIVE FOR T-6: PRECIPITATION/ GAC/ ION EXCHANGE/ SW DISCHARGE

ITEM	QUANTITY	CAPITAL COST	ANNUAL O & M COST	Present Worth of Annual Costs 30 years, 5%	Present Worth of Annual Costs 30 years, 10%
I. Administrative Actions					
1. Institutional Restrictions/Emergency Provisions (a)		$15,000			
2. Public Education Program (b)		$20,000			
3. Program Oversight (c)			$75,000	$1,153,000	$707,000
Subtotal:		$35,000	$75,000	$1,153,000	$707,000
II. GENERAL ACTIONS/SITE PREPARATION					
1. Parking/Staging Area (d)	1200 sq ft	$1,000			
2. Treatment System Building Construction (e)	7500 sq ft	$150,000			
3. Building Lighting and Heating (f)		$35,000	$7,000	$108,000	$66,000
4. Contractor Mobilization/ Demobilization		$20,000			
Subtotal:		$206,000	$7,000	$108,000	$66,000
III. GROUNDWATER TREATMENT SYSTEM					
1. Pre-treatment System (Precipitation) (g)		$850,000	$200,000	$3,074,000	$1,885,000
2. Granular Activated Carbon (GAC) Adsorption Unit (h)		$165,000	$956,000	$14,696,000	$9,012,000
3. Ion Exchange (i)		$0	$964,000	$14,819,000	$9,088,000
4. Part-time System Operator (j)	2180 hrs/yr	$8,000	$44,000	$676,000	$415,000
Subtotal:		$1,023,000	$2,164,000	$33,265,000	$20,400,000
IV. SURFACE WATER DISCHARGE SYSTEM					
1. Horizontal Pumps	3 pumps	$11,000	$26,000	$400,000	$245,000
2. Discharge Piping	8500 ft	$601,000			
3. System Controls		$25,000			
Subtotal:		$637,000	$26,000	$400,000	$245,000
V. LONG-TERM MONITORING & REVIEW					
1. Weekly Effluent & Monthly Residuals Monitoring (k)		$200,000	$121,000	$1,860,000	$1,141,000
2. Quarterly Groundwater Monitoring and Reporting (l)	6 wells		$67,000	$1,030,000	$632,000
3. Quarterly Surface Water Monitoring & Reporting (m)			$67,000	$1,030,000	$632,000
4. Five-Year Reviews ($15,000 ea)	6 reports		$3,000	$46,000	$28,000
Subtotal:		$200,000	$258,000	$3,966,000	$2,433,000
SUBTOTAL (I, II, III, IV and V)		$2,101,000	$2,530,000	$38,892,000	$23,851,000
VI. ADDITIONAL SYSTEM COSTS					
1. Health and Safety 10% of Capital subtotal		$210,000			
2. Bid Contingency 15% of Capital subtotal		$315,000			
3. Scope Contingency 15% of Capital subtotal		$315,000			
25% of Annual subtotal			$633,000	$9,731,000	$5,967,000
Subtotal:		$840,000	$633,000	$9,731,000	$5,967,000
CONSTRUCTION SUBTOTAL (I, II, III, IV, V and VI)		$2,941,000	$3,163,000	$48,623,000	$29,818,000
VII. IMPLEMENTATION COST					
1. Eng. Services During Construction 15% of system subtotal		$441,000			
2. Engineering & Design 10% of system subtotal		$294,000			
3. Permitting/ Coordination (n)		$25,000			
Subtotal:		$760,000			
A. TOTAL CAPITAL COSTS		$3,701,000			
B. TOTAL ANNUAL COSTS			$3,163,000		
C. TOTAL PRESENT WORTH OF ANNUAL COSTS				$48,623,000	$29,818,000
TOTAL PRESENT WORTH OF CAPITAL AND ANNUAL COSTS (A + C)				$52,324,000	$33,519,000

TABLE 6-7 SUMMARY OF COSTS FOR ALTERNATIVE FOR T-6: PRECIPITATION/ GAC/ ION EXCHANGE/ SW DISCHARGE

NOTES AND ASSUMPTIONS

(a) - For controlling access to contaminated areas, restricting future property use, and restricting the drilling of new drinking water wells.

(b) - To increase public awareness of hazards through press releases, presentations, and posting of signs.

(c) - Costs include the annual salary of one program oversight manager for the groundwater treatment program. Costs do not include government oversight of this task.

(d) - 30 ft x 40 ft staging area of 8" deep gravel.

(e) - Includes a 75 ft x 100 ft prefabricated steel building, 6" concrete base, insulation, electrical wiring, and plumbing.

(f) - Lighting consists of 25 8' fluorescent lights.

(g) - Includes electrochemical precipitation system consisting of a reactor, a clarifier, a granular media filtration unit, a filter press, assorted pumps and tanks. Operating costs of $0.25/ 1000gal wastewater include power and maintenance. The amount of sludge removed is estimated at 15 cubic feet/day @ $180/55 gal drum.

(h) - Includes 2 20,000lb absorbers connected in series. Annual costs include delivery and cost of activated carbon which must be replaced 15 times annually. Estimated carbon usage is approximately 1656 lbs/day.

(i) - Ion exchange unit is purchased on a lease basis. Annual costs include the replacement of ion exchange unit, maintenance of equipment, recycling of regenerative waste, and transportation of waste.

(j) - Part-time system operator is assumed to cost $20/hr and is used approximately 1 8hr shift per day. Two months operator training has been included as a capital cost.

(k) - Sixty effluent samples will be taken per year and analyzed for TAL/TCL, explosives, and cyanide. The analytical costs are $2000 per sample. The residual samples (24/year) will be tested for TCLP metals and VOCs, corrosivity, ignitability and reactivity at a cost of $700 per sample. Capital costs include 100 additional samples for TAL/TCL, explosives and cyanide which will be needed during system start-up.

(l) - The cost for well sampling is $2260 per sampling event. Six (6) wells are proposed. The analytical costs are $2000 per sample, tested for TAL/TCL, explosives and cyanide.

(m) - The cost for surface water sampling is $2260 per sampling event. Six locations are proposed to be monitored quarterly. Surface water will be tested for TAL/TCL, explosives and cyanide at a cost of $2000 per sample.

(n) - Cost includes permit application process and/or coordination with state/federal officials regarding discharge of treated water.

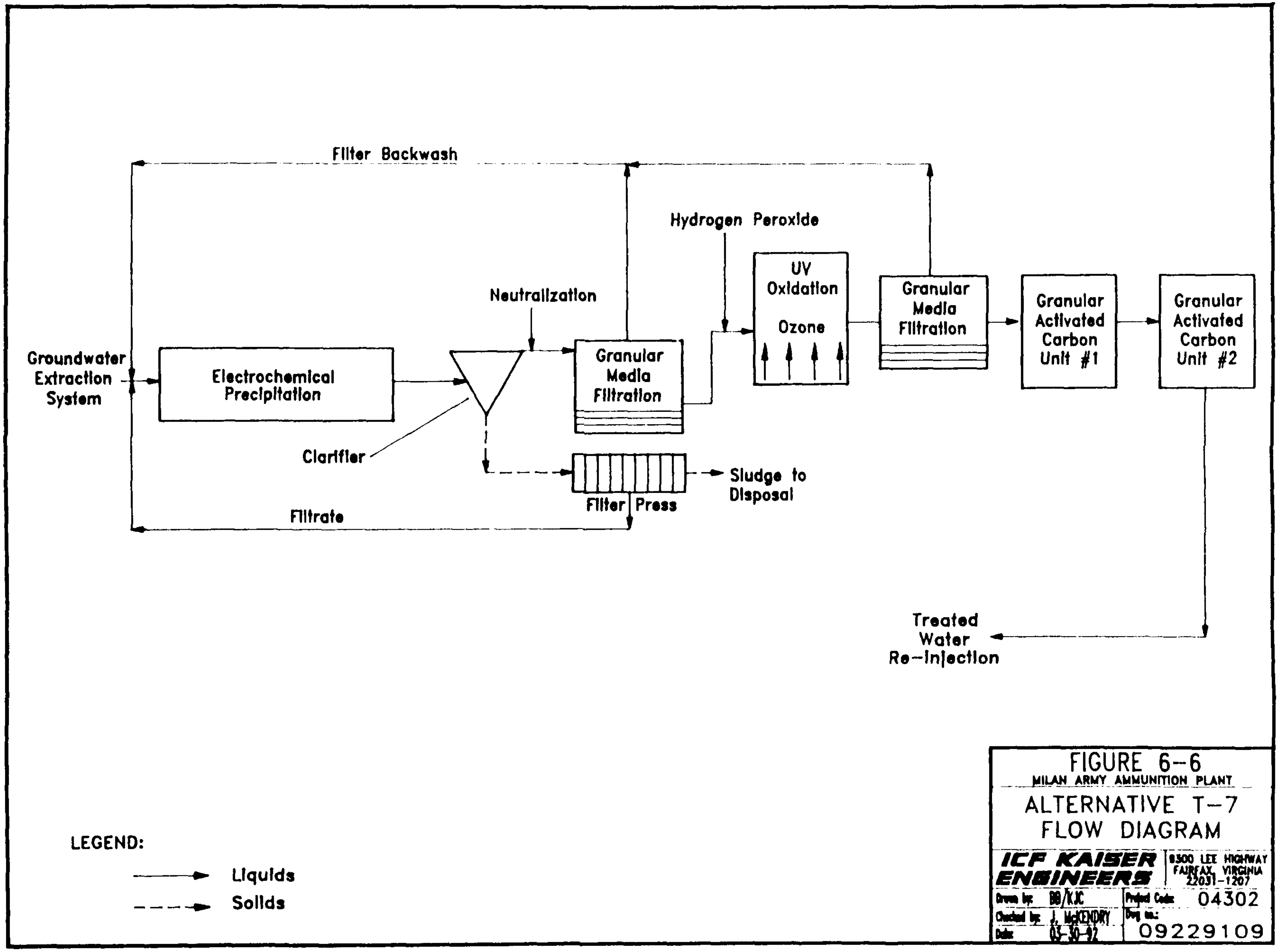


FIGURE 6-6
MILAN ARMY AMMUNITION PLANT
ALTERNATIVE T-7
FLOW DIAGRAM

through UV-oxidation. Therefore, GAC will be used at a much lower rate to complete treatment than the rates estimated in Alternatives T-5 and T-6. However, if complete oxidation is not achieved with the UV-oxidation process, organic intermediates will also be adsorbed by the carbon and this usage rate may increase. A granular media filtration unit may be needed between the UV-oxidation and GAC units to ensure that any precipitates which have formed due to oxidation of metals do not enter the GAC unit. Treated water is re-injected either upgradient or downgradient of the extraction system depending on modeling and aquifer testing (see Alternative T-3).

6.3.7.2 Overall Protection of Human Health and the Environment. This alternative will be designed to reduce the chemical concentrations in the groundwater to below the selected cleanup criteria, thus adequately protecting human health and the environment. Cleanup criteria are based on groundwater ARARs and TBCs. When combined with an extraction alternative active remediation of the contaminated groundwater will be provided, thus reducing future risk associated with the site. During the remediation activities, public health will be adequately protected through restriction of groundwater use and proper monitoring of potentially affected media.

6.3.7.3 Compliance with ARARs. It is assumed that this alternative will be operated in accordance with all Federal and Tennessee treatment facility requirements. It is also assumed that the chemical concentrations specified for groundwater treatment, whether they are statutory or risk based, are sufficiently low to meet re-injection (groundwater) discharge requirements. The treatment system itself will be designed to reduce chemical concentrations to below the specified target levels for each chemical present in the groundwater. Based on these assumptions and analyses, this alternative is expected to comply with all ARARs and TBCs related to the groundwater media.

6.3.7.4 Long-Term Effectiveness and Permanence. The treatment processes incorporated into this alternative should be capable of providing long-term effectiveness and permanence. As explained in Alternatives T-3, T-4, and T-5, sufficient operating parameters exist in the precipitation, UV-oxidation and carbon adsorption systems to allow for treatment system adjustment if groundwater quality fluctuates. Influent and effluent samples will be taken on a regular basis to check for system adjustments which may be needed over time to ensure adequate treatment of the groundwater.

Residuals generated as a result of this alternative include sludge from the precipitation unit and spent carbon. Sludge from the precipitation system is not expected to be hazardous nor is it expected to be significant in quantity. The spent carbon will not be generated in large quantities as is the case for Alternatives T-5 and T-6. Approximately 50,000 pounds of carbon will be generated each year. This carbon will be disposed properly.

Through the oxidizing capabilities of hydrogen peroxide, ozone, and the hydroxyl radicals formed as result of the UV irradiation, organics can be fully oxidized to carbon dioxide, nitrogen, water and salts. No residuals are produced from the UV-oxidation process. However, proper dosages of hydrogen peroxide and ozone, as well as oxidation time, must be provided to ensure full oxidation of these contaminants.

The actual effectiveness of this alternative for O-Line Ponds area groundwater cannot be determined without treatability testing to determine the chemical removal efficiencies of the UV-oxidation equipment combined with GAC. As stressed above, the system's capabilities are highly dependent on design parameters such as hydrogen peroxide dosage, ozone generation, and the number of UV lamps necessary for full oxidation. Carbon loading rates must also be determined. Although some data are available for many of the organic compounds found in the groundwater at the O-Line Ponds area, often these data are not representative of the concentrations detected at the site.

6.3.7.5 Reduction of Toxicity, Mobility or Volume. This alternative will address the principal threats posed by the organic and inorganic contaminants in the groundwater. Precipitation will adequately remove heavy metals in the form of a sludge. Organic contaminants will either be completely destroyed via UV-oxidation, or be adsorbed to carbon. Spent carbon will be properly disposed.

Through treatment and the proper disposal of residuals, the toxicity and volume of the contaminants are reduced. The mobility of the contaminants is reduced through the effective implementation of an extraction system. The specific design of this system is dependent on modeling and aquifer testing results.

6.3.7.6 Short-Term Effectiveness. Construction of the extraction system, treatment facility and discharge system will be completed with standard construction equipment and will entail no additional risks to workers beyond those risks inherent in construction projects. Employees and the community located within the vicinity of the site will be unaffected by the construction of the treatment facility.

Because of the rather large size of the treatment system, its design and construction may take 12-24 months. This time estimate includes the treatment system design and review, preparation of bid packages, selection of contractors and equipment suppliers, installation, and start-up.

6.3.7.7 Implementability. The treatment processes combined in this alternative are commonly used in water and wastewater treatment processes, are proven, and commercially available. Although commercially available, UV-oxidation systems are produced by only a few vendors, each with its own designs which differ greatly from one another. In addition, Andco's electrochemical precipitation process is proprietary. Because of the variables involved in the UV-oxidation and precipitation systems, the units have the flexibility to be readily adjusted if necessary in the future. Likewise, the operating parameters for the precipitation and GAC systems may be adjusted to accommodate inlet concentration fluctuations. Electricity and water are required to run this system, and both are available at the site. Approximately one-eight hour shift per day of operator oversight will be necessary to monitor this system (see Appendix C).

Due to the long period of treatment anticipated, extensive administrative oversight will be required to ensure the proper operation and maintenance and overall performance of the preferred alternative. Long-term monitoring of influent and effluent concentrations, residual characteristics, and the effectiveness of the alternative will be required. Five year reviews will also be required as part of the long-term monitoring program. Although complicated and time consuming, the tasks associated with coordinating the management of this alternative are feasible and implementable.

6.3.7.8 Cost. A summary of the costs for this alternative are given in Table 6-8. The total capital costs for the treatment system for Alternative T-7 is $2,098,000. Additional capital costs include $206,000 for site preparation and $451,000 for the installation of a re-injection system. The total present worth of this alternative is estimated to be approximately $26,980,000 (30 years, 5% discount rate), including capital costs of $5,259,000 and annual O&M expenditures of $1,413,000. These costs are preliminary and are subject to change depending on modeling, aquifer testing and treatability tests. Initial costs are based on vendor information and generic unit costs. Cost calculations are provided in Appendix C.

A description of cost sensitivity with respect to flow rate and inlet contaminant concentration for components of this alternative is given in Alternatives T-3, T-4, and T-5.

6.3.7.9 State Acceptance. Since State representatives have not been provided with a formal opportunity to review the detailed analysis of the remedial actions, no formal comments are available for evaluation of this criterion.

TABLE 6-8 SUMMARY OF COSTS FOR ALTERNATIVE FOR T-7: PRECIPITATION/ UV-OXIDATION/ GAC/ RE-INJECTION

ITEM	QUANTITY	CAPITAL COST	ANNUAL O & M COST	Present Worth of Annual Costs 30 years, 5%	Present Worth of Annual Costs 30 years, 10%
I. Administrative Actions					
1. Institutional Restrictions/Emergency Provisions (a)		$15,000			
2. Public Education Program (b)		$20,000			
3. Program Oversight (c)			$75,000	$1,153,000	$707,000
Subtotal:		$35,000	$75,000	$1,153,000	$707,000
II. GENERAL ACTIONS/SITE PREPARATION					
1. Parking/Staging Area (d)	1200 sq ft	$1,000			
2. Treatment System Building Construction (e)	7500 sq ft	$150,000			
3. Building Lighting and Heating (f)		$35,000	$7,000	$108,000	$66,000
4. Contractor Mobilization/ Demobilization		$20,000			
Subtotal:		$206,000	$7,000	$108,000	$66,000
III. GROUNDWATER TREATMENT SYSTEM					
1. Pre-treatment System (Precipitation) (g)		$850,000	$200,000	$3,074,000	$1,885,000
2. UV-Oxidation Unit (h)		$980,000	$368,000	$5,657,000	$3,469,000
3. Granular Media Filtration Unit (i)		$95,000	$53,000	$815,000	$500,000
4. Granular Activated Carbon (GAC) Adsorption Unit (j)		$165,000	$94,000	$1,445,000	$886,000
5. Part-time System Operator (k)	2180 hrs/yr	$8,000	$44,000	$676,000	$415,000
Subtotal:		$2,098,000	$759,000	$11,667,000	$7,155,000
IV. RE-INJECTION SYSTEM					
1. Injection Wells	3 wells	$99,000	$5,000	$77,000	$47,000
2. Horizontal Pumps	3 pumps	$11,000	$26,000	$400,000	$245,000
3. Discharge Piping	4450 ft	$316,000			
4. System Controls		$25,000			
Subtotal:		$451,000	$31,000	$477,000	$292,000
V. LONG-TERM MONITORING & REVIEW					
1. Weekly Effluent & Monthly Residuals Monitoring (l)		$200,000	$121,000	$1,860,000	$1,141,000
2. Quarterly Groundwater Monitoring and Reporting (m)	6 wells		$67,000	$1,030,000	$632,000
3. Quarterly Surface Water Monitoring & Reporting (n)			$67,000	$1,030,000	$632,000
4. Five-Year Reviews ($15,000 ea)	6 reports		$3,000	$46,000	$28,000
Subtotal:		$200,000	$258,000	$3,966,000	$2,433,000
SUBTOTAL (I, II, III, IV and V)		$2,990,000	$1,130,000	$17,371,000	$10,653,000
VI. ADDITIONAL SYSTEM COSTS					
1. Health and Safety — 10% of Capital subtotal		$299,000			
2. Bid Contingency — 15% of Capital subtotal		$449,000			
3. Scope Contingency — 15% of Capital subtotal		$449,000			
25% of Annual subtotal			$283,000	$4,350,000	$2,668,000
Subtotal:		$1,197,000	$283,000	$4,350,000	$2,668,000
CONSTRUCTION SUBTOTAL (I, II, III, IV, V and VI)		$4,187,000	$1,413,000	$21,721,000	$13,321,000
VII. IMPLEMENTATION COST					
1. Eng. Services During Construction 15% of system subtotal		$628,000			
2. Engineering & Design 10% of system subtotal		$419,000			
3. Permitting/ Coordination (o)		$25,000			
Subtotal:		$1,072,000			
A. TOTAL CAPITAL COSTS		$5,259,000			
B. TOTAL ANNUAL COSTS			$1,413,000		
C. TOTAL PRESENT WORTH OF ANNUAL COSTS				$21,721,000	$13,321,000
TOTAL PRESENT WORTH OF CAPITAL AND ANNUAL COSTS (A + C)				$26,980,000	$18,580,000

TABLE 6-8 SUMMARY OF COSTS FOR ALTERNATIVE FOR T-7: PRECIPITATION/ UV-OXIDATION/ GAC/ RE-INJECTION

NOTES AND ASSUMPTIONS

(a) - For controlling access to contaminated areas, restricting future property use, and restricting the drilling of new drinking water wells.
(b) - To increase public awareness of hazards through press releases, presentations, and posting of signs.
(c) - Costs include the annual salary of one program oversight manager for the groundwater treatment program. Costs do not include government oversight of this task.
(d) - 30 ft x 40 ft staging area of 8" deep gravel.
(e) - Includes a 75 ft x 100 ft prefabricated steel building, 6" concrete base, insulation, electrical wiring, and plumbing.
(f) - Lighting consists of 25 8' fluorescent lights
(g) - Includes electrochemical precipitation system consisting of a reactor, a clarifier, a granular media filtration unit, a filter press, assorted pumps and tanks. Operating costs of $0.25/ 1000gal wastewater include power and maintenance. The amount of sludge removed is estimated at 15 cubic feet/day @ $180/55 gal drum.
(h) - Includes 2 5000gal contactors, 3 reactors, and ozone generator. Operating costs include hydrogen peroxide, ozone, and electrical costs.
(i) - Includes 3 vessel multi-media filter skid with pumps, influent and effluent tanks. Operating costs of $0.20/ 1000 gal wastewater.
(j) - Includes 2 20,000lb adsorbers connected in series. Annual costs include delivery and cost of activated carbon.
(k) - Part-time system operator is assumed to cost $20/hr and is used approximately 1 8hr shift per day. Two months operator training has been included as a capital cost.
(l) - Sixty effluent samples will be taken per year and analyzed for TAL/TCL, explosives, and cyanide. The analytical costs are $2000 per sample. The residual samples (24/year) will be tested for TCLP metals and VOCs, corrosivity, ignitability and reactivity at a cost of $700 per sample. Capital costs include 100 additional samples for TAL/TCL, explosives and cyanide which will be needed during system start-up.
(m) - The cost for well sampling is $2260 per sampling event. Six (6) wells are proposed. The analytical costs are $2000 per sample, tested for TAL/TCL, explosives and cyanide.
(n) - The cost for surface water sampling is $2260 per sampling event. Six locations are proposed to be monitored quarterly. Surface water will be tested for TAL/TCL, explosives and cyanide at a cost of $2000 per sample.
(o) - Cost includes permit application process and/or coordination with state/federal officials regarding discharge of treated water.

6.3.7.10 Community Acceptance. Since the public has not been provided with a formal opportunity to review the detailed analysis of the remedial actions, no formal comments are available for evaluation of this criterion. It is anticipated that formal comments from the public will be provided during the 30-day public comment period for this FS report. These comments will then be addressed in the ROD and responsiveness summary.

6.3.8 Alternative T-8 - Precipitation/UV-Oxidation/GAC/Ion Exchange/Surface Water Discharge

6.3.8.1 Description. As in Alternative T-7, UV-oxidation and GAC are used in series to treat organics (shown schematically in Figure 6-7). Pretreatment consists of precipitation. To meet surface water discharge requirements, ion exchange (see Alternative T-4) is implemented prior to discharge. Treated water is pumped either to a nearby ditch or the Rutherford Fork of the Obion River.

6.3.8.2 Overall Protection of Human Health and the Environment. This alternative will be designed to reduce the chemical concentrations in the groundwater to below the selected cleanup criteria, thus adequately protecting human health and the environment. Cleanup criteria are based on surface water ARARs or potential risk. When combined with an extraction alternative, active remediation of the contaminated groundwater will be provided, thus reducing future risk associated with the site. During the remediation activities, public health will be adequately protected through restriction of groundwater use and proper monitoring of potentially affected media.

6.3.8.3 Compliance with ARARs. It is assumed that this alternative will be operated in accordance with all Federal and Tennessee treatment facility requirements. It is also assumed that the chemical concentrations specified for groundwater treatment, whether they are statutory or risk based, are sufficiently low to meet surface water discharge requirements. The treatment system itself will be designed to reduce chemical concentrations to below the specified target levels for each chemical present in the groundwater. Based on these assumptions and analyses, this alternative is expected to comply with all ARARs and TBCs related to the groundwater media.

6.3.8.4 Long-Term Effectiveness and Permanence. As in Alternative T-7, the treatment processes incorporated into this alternative should be capable of providing long-term effectiveness and permanence. Sufficient operating parameters exist in the chemical precipitation, UV-oxidation and carbon adsorption systems to allow for treatment system adjustment if groundwater quality fluctuates. Influent and effluent samples will be taken on a regular basis and system adjustments may be needed periodically to ensure adequate treatment of the groundwater. The ion exchange system may be replaced more or less frequently as needed.

Residuals generated as a result of this alternative include sludge from the precipitation unit, spent carbon and exhausted resin from the ion exchange system. Sludge from the precipitation system is not expected to be hazardous nor is it expected to be significant in quantity. The spent carbon must be disposed properly but will not be generated in large quantities as is the case for Alternatives T-5 and T-6.

Use of the oxidizing capabilities of hydrogen peroxide, ozone, and the hydroxyl radicals formed as result of the UV irradiation, organics can be fully oxidized to carbon dioxide, nitrogen, water and salts. If the system is properly implemented, no residuals are produced from the UV-oxidation process. Ion exchange resin will be accepted by the vendor and taken to a facility for regeneration.

The actual effectiveness of this alternative for O-Line Ponds area groundwater cannot be determined without treatability testing to determine the chemical removal efficiencies of the UV-oxidation equipment combined with GAC. Likewise, the effectiveness of precipitation combined with ion exchange must be evaluated.

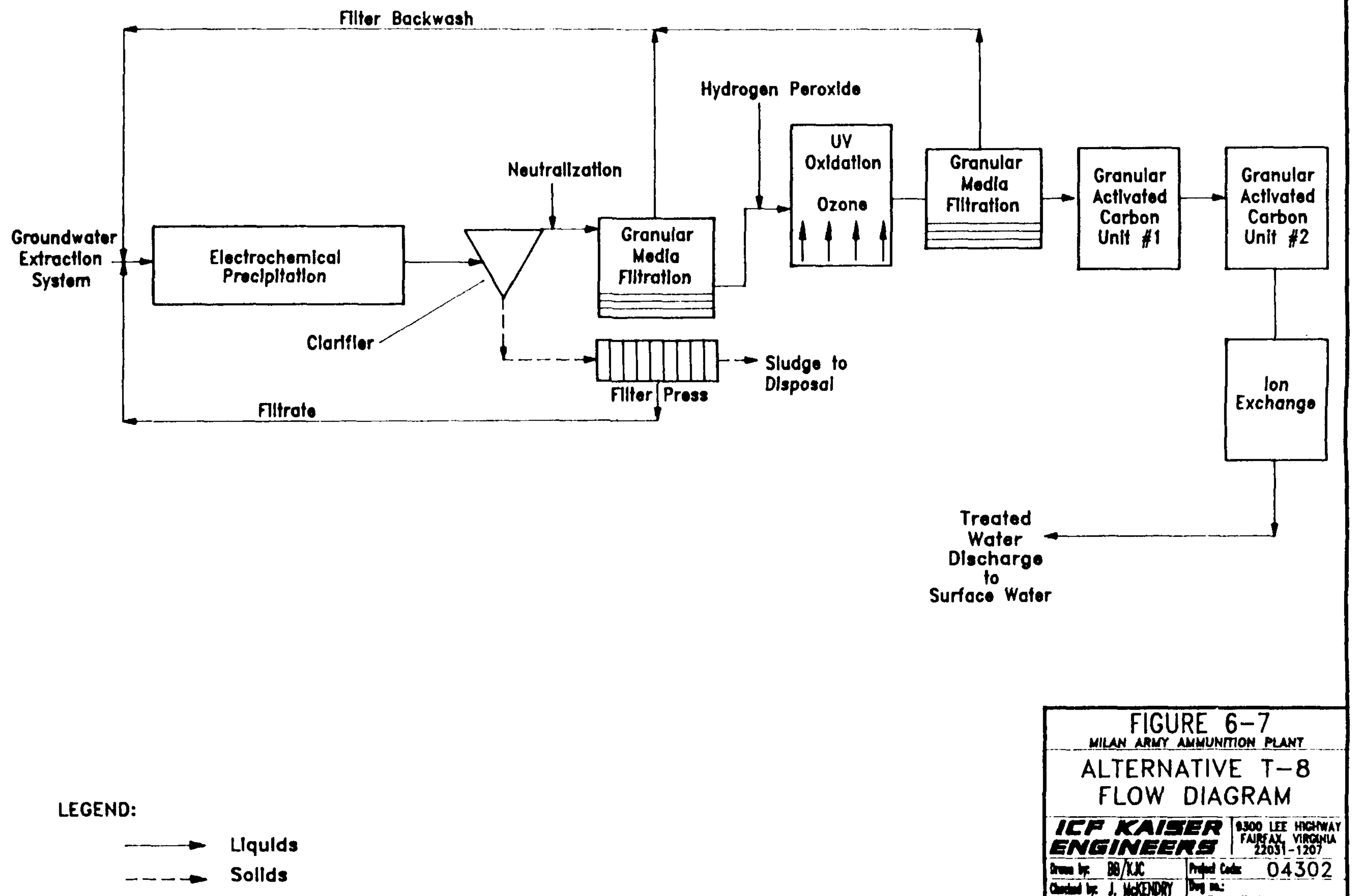


FIGURE 6-7
MILAN ARMY AMMUNITION PLANT
ALTERNATIVE T-8
FLOW DIAGRAM

ICF KAISER ENGINEERS
9300 LEE HIGHWAY
FAIRFAX, VIRGINIA
22031-1207

Drawn by: BB/KJC
Checked by: J. McKENDRY
Date: 03-30-92
Project Code: 04302
Dwg no.: 09229110

6.3.8.5 Reduction of Toxicity, Mobility or Volume. This alternative will address the principal threats posed by the organic and inorganic contaminants in the groundwater. Precipitation will adequately remove heavy metals in the form of a sludge. Organic contaminants will either be oxidized via UV-oxidation or be adsorbed to carbon. Spent carbon will be properly disposed. Metals bonded to the ion exchange resins will be recovered at an approved facility and reused.

Through treatment and the proper disposal of residuals, the toxicity and volume of the contaminants are reduced. The mobility of the contaminants is reduced through the effective implementation of an extraction system. The specific design of this system is dependent on modeling and aquifer testing results.

6.3.8.6 Short-Term Effectiveness. Construction of the extraction system, treatment facility and discharge system will be completed with standard construction equipment and will entail no additional risks to workers beyond those risks inherent in construction projects. Likewise, employees and the community located within the vicinity of the site will be unaffected by the construction of the treatment facility.

Because of the rather large size of the treatment system, its design and construction may take 12-24 months. This time estimate includes the treatment system design and review, preparation of bid packages, selection of contractors and equipment suppliers, installation, and start-up.

6.3.8.7 Implementability. The treatment processes combined in this alternative are commonly used in water and wastewater treatment processes, are proven, and commercially available. Although commercially available, UV-oxidation systems are produced by only a few vendors, each with its own designs which differ greatly from one another. In addition, Andco's electrochemical precipitation process is proprietary. Because of the variables involved in the UV-oxidation and precipitation systems, the units have the flexibility to be readily adjusted if necessary in the future. Likewise, the operating parameters for the precipitation, GAC, and ion exchange systems may be adjusted to accommodate inlet concentration fluctuations. Electricity and water are required to run this system, and both are available at the site. Approximately one-eight hour shift per day for operator oversight will be necessary to monitor this system (see Appendix C).

Due to the long period of treatment anticipated, extensive administrative oversight will be required to ensure the proper operation and maintenance and overall performance of the preferred alternative. Long-term monitoring of influent and effluent concentrations, residual characteristics, and the effectiveness of the alternative will be required. Five year reviews will also be required as part of the long-term monitoring program. Although complicated and time consuming, the tasks associated with coordinating the management of this alternative are feasible and implementable.

6.3.8.8 Cost. A summary of the costs for this alternative are given in Table 6-9. The total capital costs for the treatment system for Alternative T-8 is $2,098,000. Additional capital costs include $206,000 for site preparation and $637,000 for the installation of the surface water discharge system. The total present worth of this alternative is estimated to be approximately $45,720,000 (30 years, 5% discount rate), including capital costs of $5,583,000 and annual O&M expenditures of $2,611,000. These costs are preliminary and are subject to change depending on modeling, aquifer testing and treatability tests. Initial costs are based on vendor information and generic unit costs. Cost calculation sheets are provided in Appendix C.

A description of cost sensitivity with respect to flow rate and inlet contaminant concentration for the components of this alternative is given in Alternatives T-3, T-4, and T-5.

TABLE 6-9 SUMMARY OF COSTS FOR ALTERNATIVE FOR T 8: PRECIPITATION/ UV OXIDATION/ GAC/ ION EXCHANGE/ SW DISCHARGE

ITEM	QUANTITY	CAPITAL COST	ANNUAL O & M COST	Present Worth of Annual Costs 30 years, 5%	Present Worth of Annual Costs 30 years, 10%
I. Administrative Actions					
1. Institutional Restrictions/Emergency Provisions (a)		$15,000			
2. Public Education Program (b)		$20,000			
3. Program Oversight (c)			$75,000	$1,153,000	$707,000
Subtotal:		$35,000	$75,000	$1,153,000	$707,000
II. GENERAL ACTIONS/SITE PREPARATION					
1. Parking/Staging Area (d)	1200 sq ft	$1,000			
2. Treatment System Building Construction (e)	7500 sq ft	$150,000			
3. Building Lighting and Heating (f)		$35,000	$7,000	$108,000	$66,000
4. Contractor Mobilization/ Demobilization		$20,000			
Subtotal:		$206,000	$7,000	$108,000	$66,000
III. GROUNDWATER TREATMENT SYSTEM					
1. Pre-treatment System (Precipitation) (g)		$850,000	$200,000	$3,074,000	$1,885,000
2. UV-Oxidation Unit (h)		$980,000	$368,000	$5,657,000	$3,469,000
3. Granular Media Filtration Unit (i)		$95,000	$53,000	$815,000	$500,000
4. Granular Activated Carbon (GAC) Adsorption Unit (j)		$165,000	$94,000	$1,445,000	$886,000
5. Ion Exchange (k)		$0	$964,000	$14,819,000	$9,088,000
6. Part-time System Operator (l)	2180 hrs/yr	$8,000	$44,000	$676,000	$415,000
Subtotal:		$2,098,000	$1,723,000	$26,486,000	$16,243,000
IV. SURFACE WATER DISCHARGE SYSTEM					
1. Horizontal Pumps	3 pumps	$11,000	$26,000	$400,000	$245,000
2. Discharge Piping	8500 ft	$601,000			
3. System Controls		$25,000			
Subtotal:		$637,000	$26,000	$400,000	$245,000
V. LONG-TERM MONITORING & REVIEW					
1. Weekly Effluent & Monthly Residuals Monitoring (m)		$200,000	$121,000	$1,860,000	$1,141,000
2. Quarterly Groundwater Monitoring and Reporting (n)	6 wells		$67,000	$1,030,000	$632,000
3. Quarterly Surface Water Monitoring & Reporting (o)			$67,000	$1,030,000	$632,000
4. Five-Year Reviews ($15,000 ea)	6 reports		$3,000	$46,000	$28,000
Subtotal:		$200,000	$258,000	$3,966,000	$2,433,000
SUBTOTAL (I, II, III, IV and V)		$3,176,000	$2,089,000	$32,113,000	$19,694,000
VI. ADDITIONAL SYSTEM COSTS					
1. Health and Safety — 10% of Capital subtotal		$318,000			
2. Bid Contingency — 15% of Capital subtotal		$476,000			
3. Scope Contingency — 15% of Capital subtotal		$476,000			
25% of Annual subtotal			$522,000	$8,024,000	$4,921,000
Subtotal:		$1,270,000	$522,000	$8,024,000	$4,921,000
CONSTRUCTION SUBTOTAL (I, II, III, IV, V AND VI)		$4,446,000	$2,611,000	$40,137,000	$24,615,000
VII. IMPLEMENTATION COST					
1. Eng. Services During Construction 15% of system subtotal		$667,000			
2. Engineering & Design 10% of system subtotal		$445,000			
3. Permitting/ Coordination (p)		$2[illegible],000			
Subtotal:		$1,137,000			
A. TOTAL CAPITAL COSTS		$5,583,000			
B. TOTAL ANNUAL COSTS			$2,611,000		
C. TOTAL PRESENT WORTH OF ANNUAL COSTS				$40,137,000	$24,615,000
TOTAL PRESENT WORTH OF CAPITAL AND ANNUAL COSTS (A + C)				$45,720,000	$30,198,000

TABLE 6-9 SUMMARY OF COSTS FOR ALTERNATIVE FOR T-8: PRECIPITATION/ UV-OXIDATION/ GAC/ ION EXCHANGE/ SW DISCHARGE

NOTES AND ASSUMPTIONS

(a) - For controlling access to contaminated areas, restricting future property use, and restricting the drilling of new drinking water wells.

(b) - To increase public awareness of hazards through press releases, presentations, and posting of signs.

(c) - Costs include the annual salary of one program oversight manager for the groundwater treatment program. Costs do not include government oversight of this task.

(d) - 30 ft x 40 ft staging area of 8" deep gravel.

(e) - Includes a 75 ft x 100 ft prefabricated steel building, 6" concrete base, insulation, electrical wiring, and plumbing.

(f) - Lighting consists of 25 8' fluorescent lights

(g) - Includes electrochemical precipitation system consisting of a reactor, a clarifier, a granular media filtration unit, a filter press, assorted pumps and tanks. Operating costs of $0.25/ 1000gal wastewater include power and maintenance. The amount of sludge removed is estimated at 15 cubic feet/day @ $180/55 gal drum.

(h) - Includes 2 5000gal contactors, 3 reactors, and ozone generator. Operating costs include hydrogen peroxide, ozone, and electrical costs.

(i) - Includes 3 vessel multi-media filter skid with pumps, influent and effluent tanks. Operating costs of $0.20/ 1000 gal wastewater.

(j) - Includes 2 20,000lb absorbers connected in series. Annual costs include delivery and cost of activated carbon.

(k) - Ion exchange system is purchased on a lease basis. Annual costs include the replacement of ion exchange unit, maintenance of equipment, recycling of regenerative waste, and transportation of waste.

(l) - Part-time system operator is assumed to cost $20/hr and is used approximately 1 8hr shift per day. *Two months operator training has been included as a capital cost.*

(m) - Sixty effluent samples will be taken per year and analyzed for TAL/TCL, explosives, and cyanide. The analytical costs are $2000 per sample. The residual samples (24/year) will be tested for TCLP metals and VOCs, corrosivity, ignitability and reactivity at a cost of $700 per sample. Capital costs include 100 additional samples for TAL/TCL, explosives and cyanide which will be needed during system start-up.

(n) - The cost for well sampling is $2260 per sampling event. Six (6) wells are proposed. The analytical costs are $2000 per sample, tested for TAL/TCL, explosives and cyanide.

(o) - The cost for surface water sampling is $2260 per sampling event. Six locations are proposed to be monitored quarterly. Surface water will be tested for TAL/TCL, explosives and cyanide at a cost of $2000 per sample.

(p) - Cost includes permit application process and/or coordination with state/federal officials regarding discharge of treated water.

6.3.8.9 State Acceptance. Since State representatives have not been provided with a formal opportunity to review the detailed analysis of the remedial actions, no formal comments are available for evaluation of this criterion.

6.3.8.10 Community Acceptance. Since the public has not been provided with a formal opportunity to review the detailed analysis of the remedial actions, no formal comments are available for evaluation of this criterion. It is anticipated that formal comments from the public will be provided during the 30-day public comment period for this FS report. These comments will then be addressed in the ROD and responsiveness summary.

7.0 COMPARISON OF REMEDIAL ALTERNATIVES

The detailed evaluation performed in Section 6.0 discussed, for each remedial alternative, the degree of compliance with each of the evaluation criteria. All of the alternatives which include active treatment and discharge of groundwater (Alternatives T-3 through T-8) were evaluated to meet the threshold criteria of protection of human health and the environment and compliance with ARARs. However, each alternative meets the primary balancing criteria to different degrees. To aid in identifying and assessing relative strengths and weaknesses between the remedial alternatives, this section provides a comparative analysis of alternatives. As previously discussed, the alternatives are as follows:

- Alternative T-1, No Action;
- Alternative T-2, Limited Action;
- Alternative T-3, UV-Oxidation/Re-injection;
- Alternative T-4, Precipitation/UV-Oxidation/Ion Exchange/Surface Water Discharge;
- Alternative T-5, Precipitation/GAC/Re-injection;
- Alternative T-6, Precipitation/GAC/Ion Exchange/Surface Water Discharge;
- Alternative T-7, Precipitation/UV-Oxidation/GAC/Re-injection; and
- Alternative T-8, Precipitation/UV-Oxidation/GAC/Ion Exchange/Surface Water Discharge.

These eight alternatives are compared to highlight the differences between the alternatives, and determine their relative value in meeting seven of the nine criteria for the detailed evaluation of alternatives.

7.1 PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

Alternative T-1, No Action, will not meet this criterion since no actions are taken to eliminate, reduce or control exposure pathways. Because this alternative does not meet this threshold criterion of protection of human health and the environment, it will not be considered further in the comparison of alternatives. Alternative T-2, Limited Action, does provide some protection in that it limits access to, and use of, the contaminated groundwater through institutional controls. However, these controls do not permanently reduce access to contaminated groundwater.

The remaining six alternatives provide protection of human health and the environment. When implemented with an extraction system, the contaminated groundwater can be contained and removed from the ground for treatment thereby eliminating the exposure pathway. Alternatives T-3 through T-8 restore the conditions of the groundwater for future use.

7.2 COMPLIANCE WITH ARARS

The Limited Action alternative, Alternative T-2, does not provide any action to reduce the levels of explosive compounds which are presently above the health advisories. Over long periods of time, levels may decrease due to natural degradation and dilution. In this case, eventual compliance with ARARs may be achieved. However, the length of time before this occurs may be extensive. Because this alternative does not meet this threshold requirement of compliance with ARARs, it will not be considered further in the comparison of alternatives.

The remaining alternatives are capable of meeting either groundwater ARARs and to-be-considered guidance or surface water ARARs. Alternatives T-3, T-5 and T-7 are capable of treating the contaminants present to levels acceptable for re-injection (in compliance with groundwater ARARs and

to-be-considered guidance). Alternatives T-4, T-6, and T-8 incorporate additional treatment technologies to meet surface water ARARs.

7.3 LONG-TERM EFFECTIVENESS AND PERMANENCE

Each of the remaining alternatives provide long-term effectiveness and permanence. Alternatives using UV-oxidation are the most effective in the long-term and the most permanent because, if properly designed and optimized, this process leaves no residual waste. However, if complete oxidation is not achieved, intermediates could be formed which may be toxic. Alternatives T-3, T-4, T-7 and T-8 all use UV-oxidation as a method of removing organic compounds from groundwater. Alternative T-3 implements only GMF and UV-oxidation. The only residuals are suspended solids retained by the filtration unit. Therefore, it is has the potential to be very effective in the long term and very permanent. In addition, UV-oxidation can easily be adjusted to accommodate future fluctuations in groundwater contaminant levels. The processes used in Alternative T-4 generate sludge and exhausted resin from the additional inorganics treatment (precipitation and ion exchange) implemented. These residuals must be disposed properly. Residuals generation is more of a concern in the remaining alternatives which utilize GAC. Alternative T-7 and T-8 utilize GAC as a polishing step and, therefore, generate a moderate amount of spent carbon. However, this polishing step ensures that intermediates which may be generated by the UV-oxidation system are not discharged. Alternatives T-5 and T-6 use GAC alone for the removal of organics and, therefore, generate large quantities of spent carbon. Alternatives T-5 through T-8 also generate residuals associated with inorganics removal. All four of these alternatives implement precipitation, which produces a sludge and Alternatives T-6 and T-8 implement ion exchange which generates exhausted resin. These residuals in addition to the spent carbon, must be disposed.

The actual effectiveness of these alternatives for the O-Line Ponds area groundwater cannot be determined without treatability testing to determine the chemical removal efficiencies of the various treatment systems. Design criteria such as hydrogen peroxide dosage, ozone generation, the intensity of the UV irradiation for full oxidation, and holding time are crucial to the long-term effectiveness and permanence of the UV-oxidation system used in Alternatives T-3, T-4, T-7 and T-8. Ferrous ion dosages and optimum pH must be determined for the precipitation system used in Alternatives T-4, T-5, T-6, T-7 and T-8. For Alternatives T-5, T-6, T-7, and T-8 which utilize GAC, contact time with the carbon, the type of carbon used, and carbon loading must be determined to establish long-term effectiveness and permanence of this process.

7.4 REDUCTION OF TOXICITY, MOBILITY AND VOLUME THROUGH TREATMENT

Alternatives T-3 through T-8, when used with an extraction alternative, all provide reduction of toxicity, mobility and volume. Each alternative has the potential to treat contaminants to below the specified ARARs. Those alternatives which produce the smallest amount of residuals reduce the toxicity and volume most permanently. Alternative T-3 produces the least amount of residuals which come only from a filtration unit used prior to UV-oxidation. Alternative T-4 produces a minimal amount of residuals which include sludge from the precipitation unit and exhausted resin from the ion exchange units.

Alternative T-7 generates a moderate quantity of spent carbon as well as sludge from the precipitation process. Alternative T-8 generates the same residuals as Alternative T-7, in addition to exhausted ion exchange resin. The largest quantities of residuals are produced by Alternative T-5 and T-6 which use GAC alone for organics treatment. Between these two, Alternative T-6 generates more residuals than T-5 because ion exchange is also utilized.

7.5 SHORT-TERM EFFECTIVENESS

Alternatives T-3 through T-8 would take approximately equal amounts of time and effort to implement. All alternatives require that a treatment plant be built and that a discharge system such as a series of re-injection wells or a fairly lengthy surface water discharge line be set up. No additional risks are incurred in the implementation of one alternative as compared to another.

7.6 IMPLEMENTABILITY

All of the alternatives are relatively easy to implement and readily available. However, some alternatives are easier to implement over the long term due to their relatively low maintenance and replacement requirements. Alternative T-3 is the easiest to implement since this system does not require downtime for the replacement and disposal of spent carbon or ion exchange units. Alternative T-4 requires frequent replacement of ion exchange units. Alternatives T-5 through T-8 all require replacement and disposal of spent carbon. Alternatives T-5 and T-6 have higher carbon usage rates than T-7 and T-8 and must be changed more frequently. In addition, T-6 and T-8 require ion exchange unit replacement.

UV-oxidation processes used in Alternatives T-3, T-4, T-5 and T-6 are available through a limited number of vendors. Andco's electrochemical process used in Alternatives T-4 through T-8, is a proprietary system. GAC used in Alternatives T-5 through T-8, and ion exchange systems used in Alternatives T-4, T-6 and T-8, are offered by a large number of vendors.

7.7 COST

Table 7-1 provides a comparison of the costs of the remaining six alternatives.

In general, those alternatives implementing ion exchange to meet AWQC for surface water discharge (Alternatives T-4, T-6 and T-8) cost significantly more than their respective alternatives which do not use ion exchange systems and implement re-injection for discharge (Alternatives T-3, T-5, and T-7, respectively). The present worth of these alternatives is approximately $20,000,000 more than systems implementing discharge by re-injection. The additional costs are due to the frequent replacement of ion exchange units.

Of those alternatives developed for discharge to re-injection wells (Alternatives T-3, T-5 and T-7), Alternative T-3 has the lowest present worth value. Costs are low due to the relatively simple treatment scheme which incorporates only GMF and UV-oxidation. The present worth value for Alternative T-7 is only slightly higher than that for Alternative T-3. Because UV-oxidation is used as primary treatment and GAC is used as a polishing step in this alternative, the sizes of the systems are much smaller than units used in Alternatives T-3 or T-5. Considering that this alternative also implements precipitation, the costs incurred for organics treatment are greatly reduced. Alternative T-5 has the highest present worth value due to the large quantities of carbon which must be replaced and disposed.

Alternatives developed for discharge to surface water are given in order of increasing present worth cost as follows: Alternative T-8, Alternative T-4, and Alternative T-6. This order closely follows the rationale given above for Alternative T-7, Alternative T-3 and Alternative T-5, respectively. However, due to the implementation of precipitation in Alternative T-4 which was not implemented in Alternative T-3, the costs for Alternative T-4 are slightly higher than those for Alternative T-8. Overall, costs for Alternatives T-4, T-6, and T-8 are significantly higher due to the implementation of ion exchange.

TABLE 7-1
COMPARISON OF COSTS FOR GROUNDWATER TREATMENT/DISCHARGE ALTERNATIVES

Alternative	Costs
T-3: UV-Oxidation/Re-injection	Capital = $4,216,000 Annual = $1,243,000 Present Worth = $23,325,000
T-4: Precipitation/UV-Oxidation/Ion Exchange/Surface Water Discharge	Capital = $6,030,000 Annual = $2,691,000 Present Worth = $47,397,000
T-5: Precipitation/GAC/Re-injection	Capital = $3,376,000 Annual = $1,964,000 Present Worth = $33,567,000
T-6: Precipitation/GAC/Ion Exchange/Surface Water Discharge	Capital = $3,701,000 Annual = $3,163,000 Present Worth = $52,324,000
T-7: Precipitation/UV-Oxidation/GAC/Re-injection	Capital = $5,259,000 Annual = $1,413,000 Present Worth = $26,980,000
T-8: Precipitation/UV-Oxidation/GAC/Ion Exchange/Surface Water Discharge	Capital = $5,583,000 Annual = $2,611,000 Present Worth = $45,720,000

7.8 SUMMARY OF DETAILED EVALUATION

Based on the above, the following general conclusions may be drawn:

- Treating groundwater to meet re-injection criteria for inorganic analytes is less difficult and costly than meeting Ambient Water Quality Criteria. In addition, re-injection would result in more efficient extraction of contaminated groundwater due to enhanced gradient control. If upgradient re-injection is used, any residuals would be captured by the extraction system.

- Use of both UV-oxidation (primary treatment) and GAC (polishing step) appears to be preferable to using either process alone. The advantages of the two-unit system are that intermediates which may result from incomplete oxidation would be removed by the carbon and less system maintenance. Electrical costs are reduced significantly since the UV-oxidation system is not used to reduce the level of organics completely to those below health advisories. GAC usage is minimized since the concentration of organics in the influent is greatly reduced through primary treatment.

- UV-oxidation alone appears to be preferable to use of GAC alone because of greatly reduced costs and volume of treatment residuals.

Treatment test data will be collected and analyzed prior to selection of a preferred remedy. That analysis may have an impact on the preferences stated in this report.

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Wayne Sisk, USATHAMA

APPENDIX A

DEVELOPMENT OF BACKGROUND CONCENTRATIONS FOR GROUNDWATER

Development of Background Concentrations for Groundwater

Analyte	Well(s) Providing Data	Detected Concentration µg/L	Background Concentration Used for Comparison µg/L
3 Background Samples Available[a]			
Cd (U)	C-5, I-11, ZZ-3	ND (4.01)	4.01
Cd (F)	C-5, I-11, ZZ-3	ND (4.01)	4.01
Cr (U)	C-5, I-11, ZZ-3	ND (6.02)	6.02
Cr (F)	C-5, I-11, ZZ-3	ND (6.02)	6.02
Hg (U)	C-5, I-11, ZZ-3	ND (0.20)	0.20
Hg (F)	C-5, I-11, ZZ-3	ND (0.20)	0.20
Pb (U)	C-5, I-11, Z-33	23.9	23.9
Pb (F)	C-5, I-11, ZZ-3	11.1	11.1
1 Background Sample Available[b]			
Al (U)	I-11*	ND (141)	282
Ba (U)	I-11*	7.28	14.56
Ca (U)	I-11*	1,240	2,480
Co (U)	I-11*	ND (25)	50
Cu (U)	I-11*	ND (8.09)	16.2
Fe (U)	I-11*	ND (38.8)	77.6
K (U)	I-11*	771	1,542
Mn (U)	I-11*	8.75	17.5
Mg (U)	I-11*	ND (500)	1,000
Na (U)	I-11*	2,520	5,040
Ni (U)	I-11*	ND (34.3)	68.6
Zn (U)	I-11*	ND (21.1)	42.2
No Background Sample Available[c]			
Ag (F)	NA	NA	[illegible]
As (F)	NA	NA	100
V (F)	NA	NA	100

(U) Unfiltered sample
(F) Filtered sample
ND Not detected above the CRL; value in parentheses represents the detection limit
NA Not applicable
* Well I-11 was sampled for these parameters by Martin-Marietta in June 1990. Samples were analyzed in the MAAP chemical laboratory
a Background concentration value is based on maximum detected or on the detection limit
b Background concentration value is based on two times maximum detected or on two times the detection limit
c Background concentration value represents national average concentration. (Walton, 1985)

APPENDIX B

GROUNDWATER DATA FOR MI001 AND MI058

ICF KAISER ENGINEERS

Job No ______
Sheet 1 of 1

EXTRACTION SYSTEM COSTS
PIPING

DESIGNED BY NNA DATE 3
CHECKED BY MCM DATE 3.

$89C

Collection Piping

An above-ground piping collection system is assumed. The piping configuration will consist of 3" galvanized steel schedule 40 pipe with polyurethane insulation and steam injection to prevent freezing.

Unit costs

Schedule 40 galvanized steel pipe (3" diameter) - includes material + labor	$21.00/LF
Polyurethane insulation with jacket - 1½" thick - jacket constructed of polyester fabric PVC impregnated - supplied with silicone sealant for removable jacket	$9.24/LF
Total Unit Cost	$30.24/LF

Source: Installation - Accessible Products Means Site, 1991

Extraction Well	Flowrate (gpm)	Distance From Extraction Well to Treatment Plnt (feet)	Pipe Costs
EW-1	50-100	860	26,006.40
EW-2	"	400	12,096.00
EW-3	"	110	3,326.40
EW-4	"	150	4,536.00
EW-5	"	500	15,120.00
EW-6	"	850	25,704.00
6 wells	300-600 gpm	2,870 FT	86,788.80 Tot
		Freight:	2,000
			88,789.80

CALCULATIONS KE Form No E 6 Rev 12 89

Media	Site Type	Site ID	Analyte	Sample Date	Lot	Sample Number	Depth	Boolean	Value	Unit	Percent Moisture
CGW	WELL	MI001	111TCE	02/02/92	XLS	010	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI001	112TCE	02/02/92	XLS	010	0.000	LT	1.200	UGL	0.000
CGW	WELL	MI001	11DCE	02/02/92	XLS	010	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI001	11DCLE	02/02/92	XLS	010	0.000	LT	0.680	UGL	0.000
CGW	WELL	MI001	124TCB	02/02/92	XDV	002	0.000	LT	1.800	UGL	0.000
CGW	WELL	MI001	12DCE	02/02/92	XLS	010	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI001	12DCLB	02/02/92	XDV	002	0.000	LT	1.700	UGL	0.000
CGW	WELL	MI001	12DCLE	02/02/92	XLS	010	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI001	12DCLP	02/02/92	XLS	010	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI001	12DPH	02/02/92	XDV	002	0.000	ND	2.000	UGL	0.000
CGW	WELL	MI001	135TNB	02/02/92	XKP	006	0.000		750.000	UGL	0.000
CGW	WELL	MI001	13DCLB	02/02/92	XDV	002	0.000	LT	1.700	UGL	0.000
CGW	WELL	MI001	13DNB	02/02/92	XKP	006	0.000		78.000	UGL	0.000
CGW	WELL	MI001	14DCLB	02/02/92	XDV	002	0.000	LT	1.700	UGL	0.000
CGW	WELL	MI001	245TCP	02/02/92	XDV	002	0.000	LT	5.200	UGL	0.000
CGW	WELL	MI001	246TCP	02/02/92	XDV	002	0.000	LT	4.200	UGL	0.000
CGW	WELL	MI001	246TNT	02/02/92	XKP	006	0.000		6500.000	UGL	0.000
CGW	WELL	MI001	24DCLP	02/02/92	XDV	002	0.000	LT	2.900	UGL	0.000
CGW	WELL	MI001	24DMPN	02/02/92	XDV	002	0.000	LT	5.800	UGL	0.000
CGW	WELL	MI001	24DNP	02/02/92	XDV	002	0.000	LT	21.000	UGL	0.000
CGW	WELL	MI001	24DNT	02/02/92	XDV	002	0.000		44.000	UGL	0.000
CGW	WELL	MI001	24DNT	02/02/92	XKP	006	0.000		66.000	UGL	0.000
CGW	WELL	MI001	26DNT	02/02/92	XDV	002	0.000		7.610	UGL	0.000
CGW	WELL	MI001	26DNT	02/02/92	XKP	006	0.000		16.000	UGL	0.000
CGW	WELL	MI001	2CLEVE	02/02/92	XLS	010	0.000	LT	0.710	UGL	0.000
CGW	WELL	MI001	2CLP	02/02/92	XDV	002	0.000	LT	0.990	UGL	0.000
CGW	WELL	MI001	2CNAP	02/02/92	XDV	002	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI001	2MNAP	02/02/92	XDV	002	0.000	LT	1.700	UGL	0.000
CGW	WELL	MI001	2MP	02/02/92	XDV	002	0.000	LT	3.900	UGL	0.000
CGW	WELL	MI001	2NANIL	02/02/92	XDV	002	0.000	LT	4.300	UGL	0.000
CGW	WELL	MI001	2NP	02/02/92	XDV	002	0.000	LT	3.700	UGL	0.000
CGW	WELL	MI001	33DCBD	02/02/92	XDV	002	0.000	LT	12.000	UGL	0.000
CGW	WELL	MI001	3NANIL	02/02/92	XDV	002	0.000	LT	4.900	UGL	0.000
CGW	WELL	MI001	46DN2C	02/02/92	XDV	002	0.000	LT	17.000	UGL	0.000
CGW	WELL	MI001	4BRPPE	02/02/92	XDV	002	0.000	LT	4.200	UGL	0.000
CGW	WELL	MI001	4CANIL	02/02/92	XDV	002	0.000	LT	7.300	UGL	0.000
CGW	WELL	MI001	4CL3C	02/02/92	XDV	002	0.000	LT	4.000	UGL	0.000
CGW	WELL	MI001	4CLPPE	02/02/92	XDV	002	0.000	LT	5.100	UGL	0.000
CGW	WELL	MI001	4MP	02/02/92	XDV	002	0.000	LT	0.520	UGL	0.000
CGW	WELL	MI001	4NANIL	02/02/92	XDV	002	0.000	LT	5.200	UGL	0.000
CGW	WELL	MI001	4NP	02/02/92	XDV	002	0.000	LT	12.000	UGL	0.000
CGW	WELL	MI001	ABHC	02/02/92	XDV	002	0.000	ND	4.000	UGL	0.000
CGW	WELL	MI001	ACET	02/02/92	XLS	010	0.000	LT	13.000	UGL	0.000
CGW	WELL	MI001	ACLDAN	02/02/92	XDV	002	0.000	ND	5.100	UGL	0.000
CGW	WELL	MI001	ACROLN	02/02/92	XLS	010	0.000	ND	100.000	UGL	0.000
CGW	WELL	MI001	ACRYLO	02/02/92	XLS	010	0.000	ND	100.000	UGL	0.000
CGW	WELL	MI001	AENSLF	02/02/92	XDV	002	0.000	ND	9.200	UGL	0.000

Media	Site Type	Site ID	Analyte	Sample Date	Lot	Sample Number	Depth	Boolean	Value	Unit	Percent Moisture
CGW	WELL	MI001	CL2BZ	02/02/92	XLS	010	0.000	ND	10.000	UGL	0.000
CGW	WELL	MI001	CL6BZ	02/02/92	XDV	002	0.000	LT	1.600	UGL	0.000
CGW	WELL	MI001	CL6CP	02/02/92	XDV	002	0.000	LT	8.600	UGL	0.000
CGW	WELL	MI001	CL6ET	02/02/92	XDV	002	0.000	LT	1.500	UGL	0.000
CGW	WELL	MI001	CLC6H5	02/02/92	XLS	010	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI001	CO	02/02/92	WZS	018	0.000	LT	25.000	UGL	0.000
CGW	WELL	MI001	CO	02/02/92	WZS	025	0.000	LT	25.000	UGL	0.000
CGW	WELL	MI001	CR	02/02/92	WZS	018	0.000	LT	6.020	UGL	0.000
CGW	WELL	MI001	CR	02/02/92	WZS	025	0.000	LT	6.020	UGL	0.000
CGW	WELL	MI001	CS2	02/02/92	XLS	010	0.000		8.500	UGL	0.000
CGW	WELL	MI001	CU	02/02/92	WZS	018	0.000	LT	8.090	UGL	0.000
CGW	WELL	MI001	CU	02/02/92	WZS	025	0.000	LT	8.090	UGL	0.000
CGW	WELL	MI001	CYN	02/02/92	VWJ	008	0.000	LT	2.500	UGL	0.000
CGW	WELL	MI001	CYN	02/02/92	VWJ	014	0.000		26.600	UGL	0.000
CGW	WELL	MI001	DBAHA	02/02/92	XDV	002	0.000	LT	6.500	UGL	0.000
CGW	WELL	MI001	DBHC	02/02/92	XDV	002	0.000	ND	4.000	UGL	0.000
CGW	WELL	MI001	DBRCLM	02/02/92	XLS	010	0.000	LT	0.670	UGL	0.000
CGW	WELL	MI001	DBZFUR	02/02/92	XDV	002	0.000	LT	1.700	UGL	0.000
CGW	WELL	MI001	DEP	02/02/92	XDV	002	0.000	LT	2.000	UGL	0.000
CGW	WELL	MI001	DLDRN	02/02/92	XDV	002	0.000	ND	4.700	UGL	0.000
CGW	WELL	MI001	DMP	02/02/92	XDV	002	0.000	LT	1.500	UGL	0.000
CGW	WELL	MI001	DNBP	02/02/92	XDV	002	0.000	LT	3.700	UGL	0.000
CGW	WELL	MI001	DNOP	02/02/92	XDV	002	0.000	LT	15.000	UGL	0.000
CGW	WELL	MI001	ENDRN	02/02/92	XDV	002	0.000	ND	7.600	UGL	0.000
CGW	WELL	MI001	ENDRNA	02/02/92	XDV	002	0.000	ND	8.000	UGL	0.000
CGW	WELL	MI001	ENDRNK	02/02/92	XDV	002	0.000	ND	8.000	UGL	0.000
CGW	WELL	MI001	ESFSO4	02/02/92	XDV	002	0.000	ND	9.200	UGL	0.000
CGW	WELL	MI001	ETC6H5	02/02/92	XLS	010	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI001	FANT	02/02/92	XDV	002	0.000	LT	3.300	UGL	0.000
CGW	WELL	MI001	FE	02/02/92	WZS	018	0.000		2070.000	UGL	0.000
CGW	WELL	MI001	FE	02/02/92	WZS	025	0.000	LT	38.800	UGL	0.000
CGW	WELL	MI001	FLRENE	02/02/92	XDV	002	0.000	LT	3.700	UGL	0.000
CGW	WELL	MI001	GCLDAN	02/02/92	XDV	002	0.000	ND	5.100	UGL	0.000
CGW	WELL	MI001	HCBD	02/02/92	XDV	002	0.000	LT	3.400	UGL	0.000
CGW	WELL	MI001	HG	02/02/92	XCS	017	0.000		0.509	UGL	0.000
CGW	WELL	MI001	HG	02/02/92	XCS	024	0.000	LT	0.243	UGL	0.000
CGW	WELL	MI001	HMX	02/02/92	XKP	006	0.000		1200.000	UGL	0.000
CGW	WELL	MI001	HPCL	02/02/92	XDV	002	0.000	ND	2.000	UGL	0.000
CGW	WELL	MI001	HPCLE	02/02/92	XDV	002	0.000	ND	5.000	UGL	0.000
CGW	WELL	MI001	ICDPYR	02/02/92	XDV	002	0.000	LT	8.600	UGL	0.000
CGW	WELL	MI001	ISOPHR	02/02/92	XDV	002	0.000	LT	4.800	UGL	0.000
CGW	WELL	MI001	K	02/02/92	WZS	018	0.000		1910.000	UGL	0.000
CGW	WELL	MI001	K	02/02/92	WZS	025	0.000		1500.000	UGL	0.000
CGW	WELL	MI001	LIN	02/02/92	XDV	002	0.000	ND	4.000	UGL	0.000
CGW	WELL	MI001	MEC6H5	02/02/92	XLS	010	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI001	MEK	02/02/92	XLS	010	0.000	LT	6.400	UGL	0.000
CGW	WELL	MI001	MEXCLR	02/02/92	XDV	002	0.000	ND	5.100	UGL	0.000

Media	Site Type	Site ID	Analyte	Sample Date	Lot	Sample Number	Depth	Boolean	Value	Unit	Percent Moisture
CGW	WELL	MI001	MG	02/02/92	WZS	018	0.000		1120.000	UGL	0.000
CGW	WELL	MI001	MG	02/02/92	WZS	025	0.000		4810.000	UGL	0.000
CGW	WELL	MI001	MIBK	02/02/92	XLS	010	0.000	LT	3.000	UGL	0.000
CGW	WELL	MI001	MN	02/02/92	WZS	018	0.000		218.000	UGL	0.000
CGW	WELL	MI001	MN	02/02/92	WZS	025	0.000		974.000	UGL	0.000
CGW	WELL	MI001	MNBK	02/02/92	XLS	010	0.000	LT	3.600	UGL	0.000
CGW	WELL	MI001	NA	02/02/92	WZS	018	0.000		1200000.00[illegible]	UGL	0.000
CGW	WELL	MI001	NA	02/02/92	WZS	025	0.000		5680.0[illegible]	[illegible]GL	0.000
CGW	WELL	MI001	NAP	02/02/92	XDV	002	0.000	LT	0.50[illegible]	[illegible]GL	0.000
CGW	WELL	MI001	NB	02/02/92	XDV	002	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI001	NB	02/02/92	XKP	006	0.000		70.900	UGL	0.000
CGW	WELL	MI001	NG	02/02/92	XZB	005	0.000	LT	10.000	UGL	0.000
CGW	WELL	MI001	NI	02/02/92	WZS	018	0.000	LT	34.300	UGL	0.000
CGW	WELL	MI001	NI	02/02/92	WZS	025	0.000	LT	34.300	UGL	0.000
CGW	WELL	MI001	NNDMEA	02/02/92	XDV	002	0.000	ND	2.000	UGL	0.000
CGW	WELL	MI001	NNDNPA	02/02/92	XDV	002	0.000	LT	4.400	UGL	0.000
CGW	WELL	MI001	NNDPA	02/02/92	XDV	002	0.000	LT	3.000	UGL	0.000
CGW	WELL	MI001	PB	02/02/92	XWD	015	0.000	LT	1.260	UGL	0.000
CGW	WELL	MI001	PB	02/02/92	XWD	022	0.000		2.280	UGL	0.000
CGW	WELL	MI001	PCB016	02/02/92	XDV	002	0.000	ND	21.000	UGL	0.000
CGW	WELL	MI001	PCB221	02/02/92	XDV	002	0.000	ND	2[illegible].000	UGL	0.000
CGW	WELL	MI001	PCB232	02/02/92	XDV	002	0.000	ND	2[illegible]00	UGL	0.000
CGW	WELL	MI001	PCB242	02/02/92	XDV	002	0.000	ND	30.000	UGL	0.000
CGW	WELL	MI001	PCB248	02/02/92	XDV	002	0.000	ND	30.000	UGL	0.000
CGW	WELL	MI001	PCB254	02/02/92	XDV	002	0.000	ND	36.000	UGL	0.000
CGW	WELL	MI001	PCB260	02/02/92	XDV	002	0.000	ND	36.000	UGL	0.000
CGW	WELL	MI001	PCP	02/02/92	XDV	002	0.000	LT	18.000	UGL	0.000
CGW	WELL	MI001	PETN	02/02/92	XZB	005	0.000	LT	20.000	[illegible]GL	0.000
CGW	WELL	MI001	PHANTR	02/02/92	XDV	002	0.000	LT	0.50[illegible]	[illegible]GL	0.000
CGW	WELL	MI001	PHENOL	02/02/92	XDV	002	0.000	LT	9.200	[illegible]GL	0.000
CGW	WELL	MI001	PPDDD	02/02/92	XDV	002	0.000	ND	4.000	UGL	0.000
CGW	WELL	MI001	PPDDE	02/02/92	XDV	002	0.000	ND	4.700	UGL	0.000
CGW	WELL	MI001	PPDDT	02/02/92	XDV	002	0.000	ND	9.200	UGL	0.000
CGW	WELL	MI001	PYR	02/02/92	XDV	002	0.000	LT	2.800	UGL	0.000
CGW	WELL	MI001	RDX	02/02/92	XKP	006	0.000		6400.000	UGL	0.000
CGW	WELL	MI001	SB	02/02/92	WZS	018	0.000	LT	38.000	UGL	0.000
CGW	WELL	MI001	SB	02/02/92	WZS	025	0.000	LT	38.000	UGL	0.000
CGW	WELL	MI0[illegible]	SE	02/02/92	XTI	017	0.000	LT	3.020	UGL	0.000
CGW	WELL	MI0[illegible]	SE	02/02/92	XTI	022	0.000	LT	3.020	UGL	0.000
CGW	WELL	MI001	STYR	02/02/92	XLS	010	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI001	T13DCP	02/02/92	XLS	010	0.000	LT	0.700	UGL	0.000
CGW	WELL	MI001	TCLEA	02/02/92	XLS	010	0.000	LT	0.510	UGL	0.000
CGW	WELL	MI001	TCLEE	02/02/92	XLS	010	0.000	LT	1.600	UGL	0.000
CGW	WELL	MI001	TETRYL	02/02/92	XKP	006	0.000	LT	2.490	UGL	0.000
CGW	WELL	MI001	TL	02/02/92	WZS	018	0.000	LT	81.400	UGL	0.000
CGW	WELL	MI001	TL	02/02/92	WZS	025	0.000	LT	81.400	UGL	0.000
CGW	WELL	MI001	TRCLE	02/02/92	XLS	010	0.000	LT	0.500	UGL	0.000

Media	Site Type	Site ID	Analyte	Sample Date	Sample Lot Number	Depth	Boolean	Value	Unit	Percent Moisture
CGW	WELL	MI001	TXPHEN	02/02/92	XDV 002	0.000	ND	36.000	UGL	0.000
CGW	WELL	MI001	UNK551	02/02/92	XDV 002	0.000		10.000	UGL	0.000
CGW	WELL	MI001	UNK563	02/02/92	XDV 002	0.000		7.000	UGL	0.000
CGW	WELL	MI001	UNK578	02/02/92	XDV 002	0.000		30.000	UGL	0.000
CGW	WELL	MI001	UNK594	02/02/92	XDV 002	0.000		200.000	UGL	0.000
CGW	WELL	MI001	UNK595	02/02/92	XDV 002	0.000		300.000	UGL	0.000
CGW	WELL	MI001	UNK604	02/02/92	XDV 002	0.000		6.000	UGL	0.000
CGW	WELL	MI001	UNK607	02/02/92	XDV 002	0.000		20.000	UGL	0.000
CGW	WELL	MI001	V	02/02/92	WZS 018	0.000		11.500	UGL	0.000
CGW	WELL	MI001	V	02/02/92	WZS 025	0.000	LT	11.000	UGL	0.000
CGW	WELL	MI001	XYLEN	02/02/92	XLS 010	0.000	LT	0.840	UGL	0.000
CGW	WELL	MI001	ZN	02/02/92	WZS 018	0.000		25.900	UGL	0.000
CGW	WELL	MI001	ZN	02/02/92	WZS 025	0.000		52.400	UGL	0.000
CGW	WELL	MI057	111TCE	02/01/92	XLS 011	46.500	LT	0.500	UGL	0.000
CGW	WELL	MI057	112TCE	02/01/92	XLS 011	46.500	LT	1.200	UGL	0.000
CGW	WELL	MI057	11DCE	02/01/92	XLS 011	46.500	LT	0.500	UGL	0.000
CGW	WELL	MI057	11DCLE	02/01/92	XLS 011	46.500	LT	0.680	UGL	0.000
CGW	WELL	MI057	124TCB	02/01/92	XDU 002	46.500	LT	1.800	UGL	0.000
CGW	WELL	MI057	12DCE	02/01/92	XLS 011	46.500	LT	0.500	UGL	0.000
CGW	WELL	MI057	12DCLB	02/01/92	XDU 002	46.500	LT	1.700	UGL	0.000
CGW	WELL	MI057	12DCLE	02/01/92	XLS 011	46.500	LT	0.500	UGL	0.000
CGW	WELL	MI057	12DCLP	02/01/92	XLS 011	46.500	LT	0.500	UGL	0.000
CGW	WELL	MI057	12DPH	02/01/92	XDU 002	46.500	ND	2.000	UGL	0.000
CGW	WELL	MI057	135TNB	02/01/92	XKP 007	46.500	LT	0.449	UGL	0.000
CGW	WELL	MI057	13DCLB	02/01/92	XDU 002	46.500	LT	1.700	UGL	0.000
CGW	WELL	MI057	13DNB	02/01/92	XKP 007	46.500	LT	0.611	UGL	0.000
CGW	WELL	MI057	14DCLB	02/01/92	XDU 002	46.500	LT	1.700	UGL	0.000
CGW	WELL	MI057	245TCP	02/01/92	XDU 002	46.500	LT	5.200	UGL	0.000
CGW	WELL	MI057	246TCP	02/01/92	XDU 002	46.500	LT	4.200	UGL	0.000
CGW	WELL	MI057	246TNT	02/01/92	XKP 007	46.500	LT	0.635	UGL	0.000
CGW	WELL	MI057	24DCLP	02/01/92	XDU 002	46.500	LT	2.900	UGL	0.000
CGW	WELL	MI057	24DMPN	02/01/92	XDU 002	46.500	LT	5.800	UGL	0.000
CGW	WELL	MI057	24DNP	02/01/92	XDU 002	46.500	LT	21.000	UGL	0.000
CGW	WELL	MI057	24DNT	02/01/92	XDU 002	46.500	LT	4.500	UGL	0.000
CGW	WELL	MI057	24DNT	02/01/92	XKP 007	46.500	LT	0.064	UGL	0.000
CGW	WELL	MI057	26DNT	02/01/92	XDU 002	46.500	LT	0.790	UGL	0.000
CGW	WELL	MI057	26DNT	02/01/92	XKP 007	46.500	LT	0.074	UGL	0.000
CGW	WELL	MI057	2CLEVE	02/01/92	XLS 011	46.500	LT	0.710	UGL	0.000
CGW	WELL	MI057	2CLP	02/01/92	XDU 002	46.500	LT	0.990	UGL	0.000
CGW	WELL	MI057	2CNAP	02/01/92	XDU 002	46.500	LT	0.500	UGL	0.000
CGW	WELL	MI057	2MNAP	02/01/92	XDU 002	46.500	LT	1.700	UGL	0.000
CGW	WELL	MI057	2MP	02/01/92	XDU 002	46.500	LT	3.900	UGL	0.000
CGW	WELL	MI057	2NANIL	02/01/92	XDU 002	46.500	LT	4.300	UGL	0.000
CGW	WELL	MI057	2NP	02/01/92	XDU 002	46.500	LT	3.700	UGL	0.000
CGW	WELL	MI057	33DCBD	02/01/92	XDU 002	46.500	LT	12.000	UGL	0.000
CGW	WELL	MI057	3NANIL	02/01/92	XDU 002	46.500	LT	4.900	UGL	0.000
CGW	WELL	MI057	46DN2C	02/01/92	XDU 002	46.500	LT	17.000	UGL	0.000

Media	Site Type	Site ID	Analyte	Sample Date	Lot	Sample Number	Depth	Boolean	Value	Unit	Percent Moisture
CGW	WELL	MI057	4BRPPE	02/01/92	XDU	002	46.500	LT	4.200	UGL	0.000
CGW	WELL	MI057	4CANIL	02/01/92	XDU	002	46.500	LT	7.300	UGL	0.000
CGW	WELL	MI057	4CL3C	02/01/92	XDU	002	46.500	LT	4.000	UGL	0.000
CGW	WELL	MI057	4CLPPE	02/01/92	XDU	002	46.500	LT	5.100	UGL	0.000
CGW	WELL	MI057	4MP	02/01/92	XDU	002	46.500	LT	0.520	UGL	0.000
CGW	WELL	MI057	4NANIL	02/01/92	XDU	002	46.500	LT	5.200	UGL	0.000
CGW	WELL	MI057	4NP	02/01/92	XDU	002	46.500	LT	12.000	UGL	0.000
CGW	WELL	MI057	ABHC	02/01/92	XDU	002	46.500	ND	4.000	UGL	0.000
CGW	WELL	MI057	ACET	02/01/92	XLS	011	46.500	LT	13.000	UGL	0.000
CGW	WELL	MI057	ACLDAN	02/01/92	XDU	002	46.500	ND	5.100	UGL	0.000
CGW	WELL	MI057	ACROLN	02/01/92	XLS	011	46.500	ND	100.000	UGL	0.000
CGW	WELL	MI057	ACRYLO	02/01/92	XLS	011	46.500	ND	100.000	UGL	0.000
CGW	WELL	MI057	AENSLF	02/01/92	XDU	002	46.500	ND	9.200	UGL	0.000
CGW	WELL	MI057	AG	02/01/92	WZS	019	46.500	LT	4.600	UGL	0.000
CGW	WELL	MI057	AG	02/01/92	WZS	026	46.500	LT	4.600	UGL	0.000
CGW	WELL	MI057	AL	02/01/92	WZS	019	46.500	LT	141.000	UGL	0.000
CGW	WELL	MI057	AL	02/01/92	WZS	026	46.500	LT	141.000	UGL	0.000
CGW	WELL	MI057	ALDRN	02/01/92	XDU	002	46.500	ND	4.700	UGL	0.000
CGW	WELL	MI057	ANAPNE	02/01/92	XDU	002	46.500	LT	1.700	UGL	0.000
CGW	WELL	MI057	ANAPYL	02/01/92	XDU	002	46.500	LT	0.500	UGL	0.000
CGW	WELL	MI057	ANTRC	02/01/92	XDU	002	46.500	LT	0.500	UGL	0.000
CGW	WELL	MI057	AS	02/01/92	XPX	018	46.500	LT	2.540	UGL	0.000
CGW	WELL	MI057	AS	02/01/92	XPX	023	46.500	LT	2.540	UGL	0.000
CGW	WELL	MI057	B2CEXM	02/01/92	XDU	002	46.500	LT	1.500	UGL	0.000
CGW	WELL	MI057	B2CIPE	02/01/92	XDU	002	46.500	LT	5.300	UGL	0.000
CGW	WELL	MI057	B2CLEE	02/01/92	XDU	002	46.500	LT	1.900	UGL	0.000
CGW	WELL	MI057	B2EHP	02/01/92	XDU	002	46.500	LT	4.800	UGL	0.000
CGW	WELL	MI057	BA	02/01/92	WZS	019	46.500		19.400	UGL	0.000
CGW	WELL	MI057	BA	02/01/92	WZS	026	46.500		13.600	UGL	0.000
CGW	WELL	MI057	BAANTR	02/01/92	XDU	002	46.500	LT	1.600	UGL	0.000
CGW	WELL	MI057	BAPYR	02/01/92	XDU	002	46.500	LT	4.700	UGL	0.000
CGW	WELL	MI057	BBFANT	02/01/92	XDU	002	46.500	LT	5.400	UGL	0.000
CGW	WELL	MI057	BBHC	02/01/92	XDU	002	46.500	ND	4.000	UGL	0.000
CGW	WELL	MI057	BBZP	02/01/92	XDU	002	46.500	LT	3.400	UGL	0.000
CGW	WELL	MI057	BE	02/01/92	WZS	019	46.500	LT	5.000	UGL	0.000
CGW	WELL	MI057	BE	02/01/92	WZS	026	46.500	LT	5.000	UGL	0.000
CGW	WELL	MI057	BENSLF	02/01/92	XDU	002	46.500	ND	9.200	UGL	0.000
CGW	WELL	MI057	BENZID	02/01/92	XDU	002	46.500	ND	10.000	UGL	0.000
CGW	WELL	MI057	BENZOA	02/01/92	XDU	002	46.500	LT	13.000	UGL	0.000
CGW	WELL	MI057	BGHIPY	02/01/92	XDU	002	46.500	LT	6.100	UGL	0.000
CGW	WELL	MI057	BKFANT	02/01/92	XDU	002	46.500	LT	0.870	UGL	0.000
CGW	WELL	MI057	BRDCLM	02/01/92	XLS	011	46.500	LT	0.590	UGL	0.000
CGW	WELL	MI057	BZALC	02/01/92	XDU	002	46.500	LT	0.720	UGL	0.000
CGW	WELL	MI057	C13DCP	02/01/92	XLS	011	46.500	LT	0.580	UGL	0.000
CGW	WELL	MI057	C2AVE	02/01/92	XLS	011	46.500	LT	8.300	UGL	0.000
CGW	WELL	MI057	C2H3CL	02/01/92	XLS	011	46.500	LT	2.600	UGL	0.000
CGW	WELL	MI057	C2H5CL	02/01/92	XLS	011	46.500	LT	1.900	UGL	0.000

Media	Site Type	Site ID	Analyte	Sample Date	Lot	Sample Number	Depth	Boolean	Value	Unit	Percent Moisture
CGW	WELL	MI057	C6H6	02/01/92	XLS	011	46.500	LT	0.500	UGL	0.000
CGW	WELL	MI057	CA	02/01/92	WZS	019	46.500		3470.000	UGL	0.000
CGW	WELL	MI057	CA	02/01/92	WZS	026	46.500		2810.000	UGL	0.000
CGW	WELL	MI057	CCL3F	02/01/92	XLS	011	46.500	LT	1.400	UGL	0.000
CGW	WELL	MI057	CCL4	02/01/92	XLS	011	46.500	LT	0.580	UGL	0.000
CGW	WELL	MI057	CD	02/01/92	WZS	019	46.500	LT	4.010	UGL	0.000
CGW	WELL	MI057	CD	02/01/92	WZS	026	46.500	LT	4.010	UGL	0.000
CGW	WELL	MI057	CH2CL2	02/01/92	XLS	011	46.500	LT	2.300	UGL	0.000
CGW	WELL	MI057	CH3BR	02/01/92	XLS	011	46.500	LT	5.800	UGL	0.000
CGW	WELL	MI057	CH3CL	02/01/92	XLS	011	46.500	LT	3.200	UGL	0.000
CGW	WELL	MI057	CHBR3	02/01/92	XLS	011	46.500	LT	2.600	UGL	0.000
CGW	WELL	MI057	CHCL3	02/01/92	XLS	011	46.500	LT	0.500	UGL	0.000
CGW	WELL	MI057	CHRY	02/01/92	XDU	002	46.500	LT	2.400	UGL	0.000
CGW	WELL	MI057	CL2BZ	02/01/92	XLS	011	46.500	ND	10.000	UGL	0.000
CGW	WELL	MI057	CL6BZ	02/01/92	XDU	002	46.500	LT	1.600	UGL	0.000
CGW	WELL	MI057	CL6CP	02/01/92	XDU	002	46.500	LT	8.600	UGL	0.000
CGW	WELL	MI057	CL6ET	02/01/92	XDU	002	46.500	LT	1.500	UGL	0.000
CGW	WELL	MI057	CLC6H5	02/01/92	XLS	011	46.500	LT	0.500	UGL	0.000
CGW	WELL	MI057	CO	02/01/92	WZS	019	46.500	LT	25.000	UGL	0.000
CGW	WELL	MI057	CO	02/01/92	WZS	026	46.500	LT	25.000	UGL	0.000
CGW	WELL	MI057	CR	02/01/92	WZS	019	46.500	LT	6.020	UGL	0.000
CGW	WELL	MI057	CR	02/01/92	WZS	026	46.500	LT	6.020	UGL	0.000
CGW	WELL	MI057	CS2	02/01/92	XLS	011	46.500		36.300	UGL	0.000
CGW	WELL	MI057	CU	02/01/92	WZS	019	46.500	LT	8.090	UGL	0.000
CGW	WELL	MI057	CU	02/01/92	WZS	026	46.500	LT	8.090	UGL	0.000
CGW	WELL	MI057	CYN	02/01/92	VWJ	009	46.500	LT	2.500	UGL	0.000
CGW	WELL	MI057	CYN	02/01/92	VWJ	015	46.500	LT	2.500	UGL	0.000
CGW	WELL	MI057	DBAHA	02/01/92	XDU	002	46.500	LT	6.500	UGL	0.000
CGW	WELL	MI057	DBHC	02/01/92	XDU	002	46.500	ND	4.000	UGL	0.000
CGW	WELL	MI057	DBRCLM	02/01/92	XLS	011	46.500	LT	0.670	UGL	0.000
CGW	WELL	MI057	DBZFUR	02/01/92	XDU	002	46.500	LT	1.700	UGL	0.000
CGW	WELL	MI057	DEP	02/01/92	XDU	002	46.500	LT	2.000	UGL	0.000
CGW	WELL	MI057	DLDRN	02/01/92	XDU	002	46.500	ND	4.700	UGL	0.000
CGW	WELL	MI057	DMP	02/01/92	XDU	002	46.500	LT	1.500	UGL	0.000
CGW	WELL	MI057	DNBP	02/01/92	XDU	002	46.500	LT	3.700	UGL	0.000
CGW	WELL	MI057	DNOP	02/01/92	XDU	002	46.500	LT	15.000	UGL	0.000
CGW	WELL	MI057	ENDRN	02/01/92	XDU	002	46.500	ND	7.600	UGL	0.000
CGW	WELL	MI057	ENDRNA	02/01/92	XDU	002	46.500	ND	8.000	UGL	0.000
CGW	WELL	MI057	ENDRNK	02/01/92	XDU	002	46.500	ND	8.000	UGL	0.000
CGW	WELL	MI057	ESFSO4	02/01/92	XDU	002	46.500	ND	9.200	UGL	0.000
CGW	WELL	MI057	ETC6H5	02/01/92	XLS	011	46.500	LT	0.500	UGL	0.000
CGW	WELL	MI057	FANT	02/01/92	XDU	002	46.500	LT	3.300	UGL	0.000
CGW	WELL	MI057	FE	02/01/92	WZS	019	46.500		50.600	UGL	0.000
CGW	WELL	MI057	FE	02/01/92	WZS	026	46.500	LT	38.800	UGL	0.000
CGW	WELL	MI057	FLRENE	02/01/92	XDU	002	46.500	LT	3.700	UGL	0.000
CGW	WELL	MI057	GCLDAN	02/01/92	XDU	002	46.500	ND	5.100	UGL	0.000
CGW	WELL	MI057	HCBD	02/01/92	XDU	002	46.500	LT	3.400	UGL	0.000

Media	Site Type	Site ID	Analyte	Sample Date	Lot	Sample Number	Depth	Boolean	Value	Unit	Percent Moisture
CGW	WELL	MI057	HG	02/01/92	XCS	018	46.500	LT	0.243	UGL	0.000
CGW	WELL	MI057	HG	02/01/92	XCS	025	46.500	LT	0.243	UGL	0.000
CGW	WELL	MI057	HMX	02/01/92	XKP	007	46.500	LT	1.210	UGL	0.000
CGW	WELL	MI057	HPCL	02/01/92	XDU	002	46.500	ND	2.000	UGL	0.000
CGW	WELL	MI057	HPCLE	02/01/92	XDU	002	46.500	ND	5.000	UGL	0.000
CGW	WELL	MI057	ICDPYR	02/01/92	XDU	002	46.500	LT	8.600	UGL	0.000
CGW	WELL	MI057	ISOPHR	02/01/92	XDU	002	46.500	LT	4.800	UGL	0.000
CGW	WELL	MI057	K	02/01/92	WZS	019	46.500		2860.000	UGL	0.000
CGW	WELL	MI057	K	02/01/92	WZS	026	46.500		3010.000	UGL	0.000
CGW	WELL	MI057	LIN	02/01/92	XDU	002	46.500	ND	4.000	UGL	0.000
CGW	WELL	MI057	MEC6H5	02/01/92	XLS	011	46.500	LT	0.500	UGL	0.000
CGW	WELL	MI057	MEK	02/01/92	XLS	011	46.500	LT	6.400	UGL	0.000
CGW	WELL	MI057	MEXCLR	02/01/92	XDU	002	46.500	ND	5.100	UGL	0.000
CGW	WELL	MI057	MG	02/01/92	WZS	019	46.500		841.000	UGL	0.000
CGW	WELL	MI057	MG	02/01/92	WZS	026	46.500		868.000	UGL	0.000
CGW	WELL	MI057	MIBK	02/01/92	XLS	011	46.500	LT	3.000	UGL	0.000
CGW	WELL	MI057	MN	02/01/92	WZS	019	46.500		32.600	UGL	0.000
CGW	WELL	MI057	MN	02/01/92	WZS	026	46.500		23.700	UGL	0.000
CGW	WELL	MI057	MNBK	02/01/92	XLS	011	46.500	LT	3.600	UGL	0.000
CGW	WELL	MI057	NA	02/01/92	WZS	019	46.500		4280.000	UGL	0.000
CGW	WELL	MI057	NA	02/01/92	WZS	026	46.500		4410.000	UGL	0.000
CGW	WELL	MI057	NAP	02/01/92	XDU	002	46.500	LT	0.500	UGL	0.000
CGW	WELL	MI057	NB	02/01/92	XDU	002	46.500	LT	0.500	UGL	0.000
CGW	WELL	MI057	NB	02/01/92	XKP	007	46.500	LT	0.645	UGL	0.000
CGW	WELL	MI057	NI	02/01/92	WZS	019	46.500	LT	34.300	UGL	0.000
CGW	WELL	MI057	NI	02/01/92	WZS	026	46.500	LT	34.300	UGL	0.000
CGW	WELL	MI057	NNDMEA	02/01/92	XDU	002	46.500	ND	2.000	UGL	0.000
CGW	WELL	MI057	NNDNPA	02/01/92	XDU	002	46.500	LT	4.400	UGL	0.000
CGW	WELL	MI057	NNDPA	02/01/92	XDU	002	46.500	LT	3.000	UGL	0.000
CGW	WELL	MI057	PB	02/01/92	XWD	016	46.500		2.820	UGL	0.000
CGW	WELL	MI057	PB	02/01/92	XWD	023	46.500		1.410	UGL	0.000
CGW	WELL	MI057	PCB016	02/01/92	XDU	002	46.500	ND	21.000	UGL	0.000
CGW	WELL	MI057	PCB221	02/01/92	XDU	002	46.500	ND	21.000	UGL	0.000
CGW	WELL	MI057	PCB232	02/01/92	XDU	002	46.500	ND	21.000	UGL	0.000
CGW	WELL	MI057	PCB242	02/01/92	XDU	002	46.500	ND	30.000	UGL	0.000
CGW	WELL	MI057	PCB248	02/01/92	XDU	002	46.500	ND	30.000	UGL	0.000
CGW	WELL	MI057	PCB254	02/01/92	XDU	002	46.500	ND	36.000	UGL	0.000
CGW	WELL	MI057	PCB260	02/01/92	XDU	002	46.500	ND	36.000	UGL	0.000
CGW	WELL	MI057	PCP	02/01/92	XDU	002	46.500	LT	18.000	UGL	0.000
CGW	WELL	MI057	PHANTR	02/01/92	XDU	002	46.500	LT	0.500	UGL	0.000
CGW	WELL	MI057	PHENOL	02/01/92	XDU	002	46.500	LT	9.200	UGL	0.000
CGW	WELL	MI057	PPDDD	02/01/92	XDU	002	46.500	ND	4.000	UGL	0.000
CGW	WELL	MI057	PPDDE	02/01/92	XDU	002	46.500	ND	4.700	UGL	0.000
CGW	WELL	MI057	PPDDT	02/01/92	XDU	002	46.500	ND	9.200	UGL	0.000
CGW	WELL	MI057	PYR	02/01/92	XDU	002	46.500	LT	2.800	UGL	0.000
CGW	WELL	MI057	RDX	02/01/92	XKP	007	46.500	LT	1.170	UGL	0.000
CGW	WELL	MI057	SB	02/01/92	WZS	019	46.500	LT	38.000	UGL	0.000

Media	Site Type	Site ID	Analyte	Sample Date	Lot	Sample Number	Depth	Boolean	Value	Unit	Percent Moisture
CGW	WELL	MI057	SB	02/01/92	WZS	026	46.500	LT	38.000	UGL	0.000
CGW	WELL	MI057	SE	02/01/92	XTI	018	46.500	LT	3.020	UGL	0.000
CGW	WELL	MI057	SE	02/01/92	XTI	023	46.500	LT	3.020	UGL	0.000
CGW	WELL	MI057	STYR	02/01/92	XLS	011	46.500	LT	0.500	UGL	0.000
CGW	WELL	MI057	T13DCP	02/01/92	XLS	011	46.500	LT	0.700	UGL	0.000
CGW	WELL	MI057	TCLEA	02/01/92	XLS	011	46.500	LT	0.510	UGL	0.000
CGW	WELL	MI057	TCLEE	02/01/92	XLS	011	46.500	LT	1.600	UGL	0.000
CGW	WELL	MI057	TETRYL	02/01/92	XKP	007	46.500	LT	2.490	UGL	0.000
CGW	WELL	MI057	TL	02/01/92	WZS	019	46.500	LT	[illegible]1.400	UGL	0.000
CGW	WELL	MI057	TL	02/01/92	WZS	026	46.500	LT	81.400	UGL	0.000
CGW	WELL	MI057	TRCLE	02/01/92	XLS	011	46.500	LT	0.500	UGL	0.000
CGW	WELL	MI057	TXPHEN	02/01/92	XDU	002	46.500	ND	36.000	UGL	0.000
CGW	WELL	MI057	UNK656	02/01/92	XDU	002	46.500		6.000	UGL	0.000
CGW	WELL	MI057	UNK659	02/01/92	XDU	002	46.500		10.000	UGL	0.000
CGW	WELL	MI057	UNK668	02/01/92	XDU	002	46.500		4.000	UGL	0.000
CGW	WELL	MI057	V	02/01/92	WZS	019	46.500	LT	11.000	UGL	0.000
CGW	WELL	MI057	V	02/01/92	WZS	026	46.500	LT	11.000	UGL	0.000
CGW	WELL	MI057	XYLEN	02/01/92	XLS	011	46.500	LT	0.840	UGL	0.000
CGW	WELL	MI057	ZN	02/01/92	WZS	019	46.500		55.200	UGL	0.000
CGW	WELL	MI057	ZN	02/01/92	WZS	026	46.500		58.400	UGL	0.000
CGW	WELL	MI058	111TCE	02/02/92	XLS	012	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI058	111TCE	02/02/92	XLT	012	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI058	112TCE	02/02/92	XLS	012	0.000	LT	1.200	UGL	0.000
CGW	WELL	MI058	112TCE	02/02/92	XLT	012	0.000	LT	1.200	UGL	0.000
CGW	WELL	MI058	11DCE	02/02/92	XLS	012	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI058	11DCE	02/02/92	XLT	012	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI058	11DCLE	02/02/92	XLS	012	0.000	LT	0.680	UGL	0.000
CGW	WELL	MI058	11DCLE	02/02/92	XLT	012	0.000	LT	0.680	UGL	0.000
CGW	WELL	MI058	124TCB	02/02/92	XDV	003	0.000	LT	1.800	UGL	0.000
CGW	WELL	MI058	124TCB	02/02/92	XDV	004	0.000	LT	1.800	UGL	0.000
CGW	WELL	MI058	12DCE	02/02/92	XLS	012	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI058	12DCE	02/02/92	XLT	012	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI058	12DCLB	02/02/92	XDV	003	0.000	LT	1.700	UGL	0.000
CGW	WELL	MI058	12DCLB	02/02/92	XDV	004	0.000	LT	1.700	UGL	0.000
CGW	WELL	MI058	12DCLE	02/02/92	XLS	012	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI058	12DCLE	02/02/92	XLT	012	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI058	12DCLP	02/02/92	XLS	012	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI058	12DCLP	02/02/92	XLT	012	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI058	12DPH	02/02/92	XDV	003	0.000	ND	2.000	UGL	0.000
CGW	WELL	MI058	12DPH	02/02/92	XDV	004	0.000	ND	2.000	UGL	0.000
CGW	WELL	MI058	135TNB	02/02/92	XKP	008	0.000		2200.000	UGL	0.000
CGW	WELL	MI058	135TNB	02/02/92	XKP	009	0.000		2100.000	UGL	0.000
CGW	WELL	MI058	13DCLB	02/02/92	XDV	003	0.000	LT	1.700	UGL	0.000
CGW	WELL	MI058	13DCLB	02/02/92	XDV	004	0.000	LT	1.700	UGL	0.000
CGW	WELL	MI058	13DNB	02/02/92	XKP	008	0.000		78.000	UGL	0.000
CGW	WELL	MI058	13DNB	02/02/92	XKP	009	0.000		81.000	UGL	0.000
CGW	WELL	MI058	14DCLB	02/02/92	XDV	003	0.000	LT	1.700	UGL	0.000

Media	Site Type	Site ID	Analyte	Sample Date	Sample Lot Number	Depth	Boolean	Value	Unit	Percent Moisture
CGW	WELL	MI058	14DCLB	02/02/92	XDV 004	0.000	LT	1.700	UGL	0.000
CGW	WELL	MI058	245TCP	02/02/92	XDV 003	0.000	LT	5.200	UGL	0.000
CGW	WELL	MI058	245TCP	02/02/92	XDV 004	0.000	LT	5.200	UGL	0.000
CGW	WELL	MI058	246TCP	02/02/92	XDV 003	0.000	LT	4.200	UGL	0.000
CGW	WELL	MI058	246TCP	02/02/92	XDV 004	0.000	LT	4.200	UGL	0.000
CGW	WELL	MI058	246TNT	02/02/92	XKP 008	0.000		11000.000	UGL	0.000
CGW	WELL	MI058	246TNT	02/02/92	XKP 009	0.000		20000.000	UGL	0.000
CGW	WELL	MI058	24DCLP	02/02/92	XDV 003	0.000	LT	2.900	UGL	0.000
CGW	WELL	MI058	24DCLP	02/02/92	XDV 004	0.000	LT	2.900	UGL	0.000
CGW	WELL	MI058	24DMPN	02/02/92	XDV 003	0.000	LT	5.800	UGL	0.000
CGW	WELL	MI058	24DMPN	02/02/92	XDV 004	0.000	LT	5.800	UGL	0.000
CGW	WELL	MI058	24DNP	02/02/92	XDV 003	0.000	LT	21.000	UGL	0.000
CGW	WELL	MI058	24DNP	02/02/92	XDV 004	0.000	LT	21.000	UGL	0.000
CGW	WELL	MI058	24DNT	02/02/92	XDV 003	0.000		157.000	UGL	0.000
CGW	WELL	MI058	24DNT	02/02/92	XDV 004	0.000		168.000	UGL	0.000
CGW	WELL	MI058	24DNT	02/02/92	XKP 008	0.000		170.000	UGL	0.000
CGW	WELL	MI058	24DNT	02/02/92	XKP 009	0.000		190.000	UGL	0.000
CGW	WELL	MI058	26DNT	02/02/92	XDV 003	0.000		9.170	UGL	0.000
CGW	WELL	MI058	26DNT	02/02/92	XDV 004	0.000		10.100	UGL	0.000
CGW	WELL	MI058	26DNT	02/02/92	XKP 008	0.000		11.000	UGL	0.000
CGW	WELL	MI058	26DNT	02/02/92	XKP 009	0.000		8.590	UGL	0.000
CGW	WELL	MI058	2CLEVE	02/02/92	XLS 012	0.000	LT	0.710	UGL	0.000
CGW	WELL	MI058	2CLEVE	02/02/92	XLT 012	0.000	LT	0.710	UGL	0.000
CGW	WELL	MI058	2CLP	02/02/92	XDV 003	0.000	LT	0.990	UGL	0.000
CGW	WELL	MI058	2CLP	02/02/92	XDV 004	0.000	LT	0.990	UGL	0.000
CGW	WELL	MI058	2CNAP	02/02/92	XDV 003	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI058	2CNAP	02/02/92	XDV 004	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI058	2MNAP	02/02/92	XDV 003	0.000	LT	1.700	UGL	0.000
CGW	WELL	MI058	2MNAP	02/02/92	XDV 004	0.000	LT	1.700	UGL	0.000
CGW	WELL	MI058	2MP	02/02/92	XDV 003	0.000	LT	3.900	UGL	0.000
CGW	WELL	MI058	2MP	02/02/92	XDV 004	0.000	LT	3.900	UGL	0.000
CGW	WELL	MI058	2NANIL	02/02/92	XDV 003	0.000	LT	4.300	UGL	0.000
CGW	WELL	MI058	2NANIL	02/02/92	XDV 004	0.000	LT	4.300	UGL	0.000
CGW	WELL	MI058	2NP	02/02/92	XDV 003	0.000	LT	3.700	UGL	0.000
CGW	WELL	MI058	2NP	02/02/92	XDV 004	0.000	LT	3.700	UGL	0.000
CGW	WELL	MI058	2PROL	02/02/92	XLT 012	0.000		7.000	UGL	0.000
CGW	WELL	MI058	33DCBD	02/02/92	XDV 003	0.000	LT	12.000	UGL	0.000
CGW	WELL	MI058	33DCBD	02/02/92	XDV 004	0.000	LT	12.000	UGL	0.000
CGW	WELL	MI058	3NANIL	02/02/92	XDV 003	0.000	LT	4.900	UGL	0.000
CGW	WELL	MI058	3NANIL	02/02/92	XDV 004	0.000	LT	4.900	UGL	0.000
CGW	WELL	MI058	46DN2C	02/02/92	XDV 003	0.000	LT	17.000	UGL	0.000
CGW	WELL	MI058	46DN2C	02/02/92	XDV 004	0.000	LT	17.000	UGL	0.000
CGW	WELL	MI058	4BRPPE	02/02/92	XDV 003	0.000	LT	4.200	UGL	0.000
CGW	WELL	MI058	4BRPPE	02/02/92	XDV 004	0.000	LT	4.200	UGL	0.000
CGW	WELL	MI058	4CANIL	02/02/92	XDV 003	0.000	LT	7.300	UGL	0.000
CGW	WELL	MI058	4CANIL	02/02/92	XDV 004	0.000	LT	7.300	UGL	0.000
CGW	WELL	MI058	4CL3C	02/02/92	XDV 003	0.000	LT	4.000	UGL	0.000

Media	Site Type	Site ID	Analyte	Sample Date	Sample Lot	Number	Depth	Boolean	Value	Unit	Percent Moisture
CGW	WELL	MI058	4CL3C	02/02/92	XDV	004	0.000	LT	4.000	UGL	0.000
CGW	WELL	MI058	4CLPPE	02/02/92	XDV	003	0.000	LT	5.100	UGL	0.000
CGW	WELL	MI058	4CLPPE	02/02/92	XDV	004	0.000	LT	5.100	UGL	0.000
CGW	WELL	MI058	4MP	02/02/92	XDV	003	0.000	LT	0.520	UGL	0.000
CGW	WELL	MI058	4MP	02/02/92	XDV	004	0.000	LT	0.520	UGL	0.000
CGW	WELL	MI058	4NANIL	02/02/92	XDV	003	0.000	LT	5.200	UGL	0.000
CGW	WELL	MI058	4NANIL	02/02/92	XDV	004	0.000	LT	5.200	UGL	0.000
CGW	WELL	MI058	4NP	02/02/92	XDV	003	0.000	LT	12.000	UGL	0.000
CGW	WELL	MI058	4NP	02/02/92	XDV	004	0.000	LT	12.000	UGL	0.000
CGW	WELL	MI058	ABHC	02/02/92	XDV	003	0.000	ND	4.000	UGL	0.000
CGW	WELL	MI058	ABHC	02/02/92	XDV	004	0.000	ND	4.000	UGL	0.000
CGW	WELL	MI058	ACET	02/02/92	XLS	012	0.000	LT	13.000	UGL	0.000
CGW	WELL	MI058	ACET	02/02/92	XLT	012	0.000	LT	13.000	UGL	0.000
CGW	WELL	MI058	ACLDAN	02/02/92	XDV	003	0.000	ND	5.100	UGL	0.000
CGW	WELL	MI058	ACLDAN	02/02/92	XDV	004	0.000	ND	5.100	UGL	0.000
CGW	WELL	MI058	ACROLN	02/02/92	XLS	012	0.000	ND	100.000	UGL	0.000
CGW	WELL	MI058	ACROLN	02/02/92	XLT	012	0.000	ND	100.000	UGL	0.000
CGW	WELL	MI058	ACRYLO	02/02/92	XLS	012	0.000	ND	100.000	UGL	0.000
CGW	WELL	MI058	ACRYLO	02/02/92	XLT	012	0.000	ND	100.000	UGL	0.000
CGW	WELL	MI058	AENSLF	02/02/92	XDV	003	0.000	ND	9.200	UGL	0.000
CGW	WELL	MI058	AENSLF	02/02/92	XDV	004	0.000	ND	9.200	UGL	0.000
CGW	WELL	MI058	AG	02/02/92	WZS	020	0.000	LT	4.600	UGL	0.000
CGW	WELL	MI058	AG	02/02/92	WZS	021	0.000	LT	4.600	UGL	0.000
CGW	WELL	MI058	AG	02/02/92	WZS	027	0.000	LT	4.600	UGL	0.000
CGW	WELL	MI058	AG	02/02/92	WZS	028	0.000	LT	4.600	UGL	0.000
CGW	WELL	MI058	AL	02/02/92	WZS	020	0.000	LT	141.000	UGL	0.000
CGW	WELL	MI058	AL	02/02/92	WZS	021	0.000		173.000	UGL	0.000
CGW	WELL	MI058	AL	02/02/92	WZS	027	0.000	LT	141.000	UGL	0.000
CGW	WELL	MI058	AL	02/02/92	WZS	028	0.000	LT	141.000	UGL	0.000
CGW	WELL	MI058	ALDRN	02/02/92	XDV	003	0.000	ND	4.700	UGL	0.000
CGW	WELL	MI058	ALDRN	02/02792	XDV	004	0.000	ND	4.700	UGL	0.000
CGW	WELL	MI058	ANAPNE	02/02/92	XDV	003	0.000	LT	1.700	UGL	0.000
CGW	WELL	MI058	ANAPNE	02/02/92	XDV	004	0.000	LT	1.700	UGL	0.000
CGW	WELL	MI058	ANAPYL	02/02/92	XDV	003	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI058	ANAPYL	02/02/92	XDV	004	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI058	ANTRC	02/02/92	XDV	003	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI058	ANTRC	02/02/92	XDV	004	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI058	AS	02/02/92	XPX	019	0.000	LT	2.540	UGL	0.000
CGW	WELL	MI058	AS	02/02/92	XPX	020	0.000	LT	2.540	UGL	0.000
CGW	WELL	MI058	AS	02/02/92	XPX	024	0.000	LT	2.540	UGL	0.000
CGW	WELL	MI058	AS	02/02/92	XPX	025	0.000	LT	2.540	UGL	0.000
CGW	WELL	MI058	B2CEXM	02/02/92	XDV	003	0.000	LT	1.500	UGL	0.000
CGW	WELL	MI058	B2CEXM	02/02/92	XDV	004	0.000	LT	1.500	UGL	0.000
CGW	WELL	MI058	B2CIPE	02/02/92	XDV	003	0.000	LT	5.300	UGL	0.000
CGW	WELL	MI058	B2CIPE	02/02/92	XDV	004	0.000	LT	5.300	UGL	0.000
CGW	WELL	MI058	B2CLEE	02/02/92	XDV	003	0.000	LT	1.900	UGL	0.000
CGW	WELL	MI058	B2CLEE	02/02/92	XDV	004	0.000	LT	1.900	UGL	0.000

Media	Site Type	Site ID	Analyte	Sample Date	Lot	Sample Number	Depth	Boolean	Value	Unit	Percent Moisture
CGW	WELL	MI058	B2EHP	02/02/92	XDV	003	0.000	LT	4.800	UGL	0.000
CGW	WELL	MI058	B2EHP	02/02/92	XDV	004	0.000	LT	4.800	UGL	0.000
CGW	WELL	MI058	BA	02/02/92	WZS	020	0.000		128.000	UGL	0.000
CGW	WELL	MI058	BA	02/02/92	WZS	021	0.000		113.000	UGL	0.000
CGW	WELL	MI058	BA	02/02/92	WZS	027	0.000		100.000	UGL	0.000
CGW	WELL	MI058	BA	02/02/92	WZS	028	0.000		97.200	UGL	0.000
CGW	WELL	MI058	BAANTR	02/02/92	XDV	003	0.000	LT	1.600	UGL	0.000
CGW	WELL	MI058	BAANTR	02/02/92	XDV	004	0.000	LT	1.600	UGL	0.000
CGW	WELL	MI058	BAPYR	02/02/92	XDV	003	0.000	LT	4.700	UGL	0.000
CGW	WELL	MI058	BAPYR	02/02/92	XDV	004	0.000	LT	4.700	UGL	0.000
CGW	WELL	MI058	BBFANT	02/02/92	XDV	003	0.000	LT	5.400	UGL	0.000
CGW	WELL	MI058	BBFANT	02/02/92	XDV	004	0.000	LT	5.400	UGL	0.000
CGW	WELL	MI058	BBHC	02/02/92	XDV	003	0.000	ND	4.000	UGL	0.000
CGW	WELL	MI058	BBHC	02/02/92	XDV	004	0.000	ND	4.000	UGL	0.000
CGW	WELL	MI058	BBZP	02/02/92	XDV	003	0.000	LT	3.400	UGL	0.000
CGW	WELL	MI058	BBZP	02/02/92	XDV	004	0.000	LT	3.400	UGL	0.000
CGW	WELL	MI058	BE	02/02/92	WZS	020	0.000	LT	5.000	UGL	0.000
CGW	WELL	MI058	BE	02/02/92	WZS	021	0.000	LT	5.000	UGL	0.000
CGW	WELL	MI058	BE	02/02/92	WZS	027	0.000	LT	5.000	UGL	0.000
CGW	WELL	MI058	BE	02/02/92	WZS	028	0.000	LT	5.000	UGL	0.000
CGW	WELL	MI058	BENSLF	02/02/92	XDV	003	0.000	ND	9.200	UGL	0.000
CGW	WELL	MI058	BENSLF	02/02/92	XDV	004	0.000	ND	9.200	UGL	0.000
CGW	WELL	MI058	BENZID	02/02/92	XDV	003	0.000	ND	10.000	UGL	0.000
CGW	WELL	MI058	BENZID	02/02/92	XDV	004	0.000	ND	10.000	UGL	0.000
CGW	WELL	MI058	BENZOA	02/02/92	XDV	003	0.000	LT	13.000	UGL	0.000
CGW	WELL	MI058	BENZOA	02/02/92	XDV	004	0.000	LT	13.000	UGL	0.000
CGW	WELL	MI058	BGHIPY	02/02/92	XDV	003	0.000	LT	6.100	UGL	0.000
CGW	WELL	MI058	BGHIPY	02/02/92	XDV	004	0.000	LT	6.100	UGL	0.000
CGW	WELL	MI058	BKFANT	02/02/92	XDV	003	0.000	LT	0.870	UGL	0.000
CGW	WELL	MI058	BKFANT	02/02/92	XDV	004	0.000	LT	0.870	UGL	0.000
CGW	WELL	MI058	BRDCLM	02/02/92	XLS	012	0.000	LT	0.590	UGL	0.000
CGW	WELL	MI058	BRDCLM	02/02/92	XLT	012	0.000	LT	0.590	UGL	0.000
CGW	WELL	MI058	BZALC	02/02/92	XDV	003	0.000	LT	0.720	UGL	0.000
CGW	WELL	MI058	BZALC	02/02/92	XDV	004	0.000	LT	0.720	UGL	0.000
CGW	WELL	MI058	C13DCP	02/02/92	XLS	012	0.000	LT	0.580	UGL	0.000
CGW	WELL	MI058	C13DCP	02/02/92	XLT	012	0.000	LT	0.580	UGL	0.000
CGW	WELL	MI058	C2AVE	02/02/92	XLS	012	0.000	LT	8.300	UGL	0.000
CGW	WELL	MI058	C2AVE	02/02/92	XLT	012	0.000	LT	8.300	UGL	0.000
CGW	WELL	MI058	C2H3CL	02/02/92	XLS	012	0.000	LT	2.600	UGL	0.000
CGW	WELL	MI058	C2H3CL	02/02/92	XLT	012	0.000	LT	2.600	UGL	0.000
CGW	WELL	MI058	C2H5CL	02/02/92	XLS	012	0.000	LT	1.900	UGL	0.000
CGW	WELL	MI058	C2H5CL	02/02/92	XLT	012	0.000	LT	1.900	UGL	0.000
CGW	WELL	MI058	C6H6	02/02/92	XLS	012	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI058	C6H6	02/02/92	XLT	012	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI058	CA	02/02/92	WZS	020	0.000		23200.000	UGL	0.000
CGW	WELL	MI058	CA	02/02/92	WZS	021	0.000		20800.000	UGL	0.000
CGW	WELL	MI058	CA	02/02/92	WZS	027	0.000		19600.000	UGL	0.000

Media	Site Type	Site ID	Analyte	Sample Date	Lot	Sample Number	Depth	Boolean	Value	Unit	Percent Moisture
CGW	WELL	MI058	CA	02/02/92	WZS	028	0.000		19400.000	UGL	0.000
CGW	WELL	MI058	CCL3F	02/02/92	XLS	012	0.000	LT	1.400	UGL	0.000
CGW	WELL	MI058	CCL3F	02/02/92	XLT	012	0.000	LT	1.400	UGL	0.000
CGW	WELL	MI058	CCL4	02/02/92	XLS	012	0.000	LT	0.580	UGL	0.000
CGW	WELL	MI058	CCL4	02/02/92	XLT	012	0.000	LT	0.580	UGL	0.000
CGW	WELL	MI058	CD	02/02/92	WZS	020	0.000	LT	4.010	UGL	0.000
CGW	WELL	MI058	CD	02/02/92	WZS	021	0.000	LT	4.010	UGL	0.000
CGW	WELL	MI058	CD	02/02/92	WZS	027	0.000	LT	4.010	UGL	0.000
CGW	WELL	MI058	CD	02/02/92	WZS	028	0.000	LT	4.010	UGL	0.000
CGW	WELL	MI058	CH2CL2	02/02/92	XLS	012	0.000	LT	2.300	UGL	0.000
CGW	WELL	MI058	CH2CL2	02/02/92	XLT	012	0.000	LT	2.300	UGL	0.000
CGW	WELL	MI058	CH3BR	02/02/92	XLS	012	0.000	LT	5.800	UGL	0.000
CGW	WELL	MI058	CH3BR	02/02/92	XLT	012	0.000	LT	5.800	UGL	0.000
CGW	WELL	MI058	CH3CL	02/02/92	XLS	012	0.000	LT	3.200	UGL	0.000
CGW	WELL	MI058	CH3CL	02/02/92	XLT	012	0.000	LT	3.200	UGL	0.000
CGW	WELL	MI058	CHBR3	02/02/92	XLS	012	0.000	LT	2.600	UGL	0.000
CGW	WELL	MI058	CHBR3	02/02/92	XLT	012	0.000	LT	2.600	UGL	0.000
CGW	WELL	MI058	CHCL3	02/02/92	XLS	012	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI058	CHCL3	02/02/92	XLT	012	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI058	CHRY	02/02/92	XDV	003	0.000	LT	2.400	UGL	0.000
CGW	WELL	MI058	CHRY	02/02/92	XDV	004	0.000	LT	2.400	UGL	0.000
CGW	WELL	MI058	CL2BZ	02/02/92	XLS	012	0.000	ND	10.000	UGL	0.000
CGW	WELL	MI058	CL2BZ	02/02/92	XLT	012	0.000	ND	10.000	UGL	0.000
CGW	WELL	MI058	CL6BZ	02/02/92	XDV	003	0.000	LT	1.600	UGL	0.000
CGW	WELL	MI058	CL6BZ	02/02/92	XDV	004	0.000	LT	1.600	UGL	0.000
CGW	WELL	MI058	CL6CP	02/02/92	XDV	003	0.000	LT	8.600	UGL	0.000
CGW	WELL	MI058	CL6CP	02/02/92	XDV	004	0.000	LT	8.600	UGL	0.000
CGW	WELL	MI058	CL6ET	02/02/92	XDV	003	0.000	LT	1.500	UGL	0.000
CGW	WELL	MI058	CL6ET	02/02/92	XDV	004	0.000	LT	1.500	UGL	0.000
CGW	WELL	MI058	CLC6H5	02/02/92	XLS	012	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI058	CLC6H5	02/02/92	XLT	012	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI058	CO	02/02/92	WZS	020	0.000	LT	25.000	UGL	0.000
CGW	WELL	MI058	CO	02/02/92	WZS	021	0.000	LT	25.000	UGL	0.000
CGW	WELL	MI058	CO	02/02/92	WZS	027	0.000	LT	25.000	UGL	0.000
CGW	WELL	MI058	CO	02/02/92	WZS	028	0.000	LT	25.000	UGL	0.000
CGW	WELL	MI058	CR	02/02/92	WZS	020	0.000	LT	6.020	UGL	0.000
CGW	WELL	MI058	CR	02/02/92	WZS	021	0.000	LT	6.020	UGL	0.000
CGW	WELL	MI058	CR	02/02/92	WZS	027	0.000	LT	6.020	UGL	0.000
CGW	WELL	MI058	CR	02/02/92	WZS	028	0.000	LT	6.020	UGL	0.000
CGW	WELL	MI058	CS2	02/02/92	XLS	012	0.000		1.930	UGL	0.000
CGW	WELL	MI058	CS2	02/02/92	XLT	012	0.000		4.540	UGL	0.000
CGW	WELL	MI058	CU	02/02/92	WZS	020	0.000	LT	8.090	UGL	0.000
CGW	WELL	MI058	CU	02/02/92	WZS	021	0.000	LT	8.090	UGL	0.000
CGW	WELL	MI058	CU	02/02/92	WZS	027	0.000	LT	8.090	UGL	0.000
CGW	WELL	MI058	CU	02/02/92	WZS	028	0.000	LT	8.090	UGL	0.000
CGW	WELL	MI058	CYN	02/02/92	VWJ	010	0.000		34.900	UGL	0.000
CGW	WELL	MI058	CYN	02/02/92	VWJ	011	0.000		41.500	UGL	0.000

Media	Site Type	Site ID	Analyte	Sample Date	Lot	Sample Number	Depth	Boolean	Value	Unit	Percent Moisture
CGW	WELL	MI058	CYN	02/02/92	VWJ	016	0.000		40.100	UGL	0.000
CGW	WELL	MI058	CYN	02/02/92	VWJ	017	0.000		46.200	UGL	0.000
CGW	WELL	MI058	DBAHA	02/02/92	XDV	003	0.000	LT	6.500	UGL	0.000
CGW	WELL	MI058	DBAHA	02/02/92	XDV	004	0.000	LT	6.500	UGL	0.000
CGW	WELL	MI058	DBHC	02/02/92	XDV	003	0.000	ND	4.000	UGL	0.000
CGW	WELL	MI058	DBHC	02/02/92	XDV	004	0.000	ND	4.000	UGL	0.000
CGW	WELL	MI058	DBRCLM	02/02/92	XLS	012	0.000	LT	0.670	UGL	0.000
CGW	WELL	MI058	DBRCLM	02/02/92	XLT	012	0.000	LT	0.670	UGL	0.000
CGW	WELL	MI058	DBZFUR	02/02/92	XDV	003	0.000	LT	1.700	UGL	0.000
CGW	WELL	MI058	DBZFUR	02/02/92	XDV	004	0.000	LT	1.700	UGL	0.000
CGW	WELL	MI058	DEP	02/02/92	XDV	003	0.000	LT	2.000	UGL	0.000
CGW	WELL	MI058	DEP	02/02/92	XDV	004	0.000	LT	2.000	UGL	0.000
CGW	WELL	MI058	DLDRN	02/02/92	XDV	003	0.000	ND	4.700	UGL	0.000
CGW	WELL	MI058	DLDRN	02/02/92	XDV	004	0.000	ND	4.700	UGL	0.000
CGW	WELL	MI058	DMP	02/02/92	XDV	003	0.000	LT	1.500	UGL	0.000
CGW	WELL	MI058	DMP	02/02/92	XDV	004	0.000	LT	1.500	UGL	0.000
CGW	WELL	MI058	DNBP	02/02/92	XDV	003	0.000	LT	3.700	UGL	0.000
CGW	WELL	MI058	DNBP	02/02/92	XDV	004	0.000	LT	3.700	UGL	0.000
CGW	WELL	MI058	DNOP	02/02/92	XDV	003	0.000	LT	15.000	UGL	0.000
CGW	WELL	MI058	DNOP	02/02/92	XDV	004	0.000	LT	15.000	UGL	0.000
CGW	WELL	MI058	ENDRN	02/02/92	XDV	003	0.000	ND	7.600	UGL	0.000
CGW	WELL	MI058	ENDRN	02/02/92	XDV	004	0.000	ND	7.600	UGL	0.000
CGW	WELL	MI058	ENDRNA	02/02/92	XDV	003	0.000	ND	8.000	UGL	0.000
CGW	WELL	MI058	ENDRNA	02/02/92	XDV	004	0.000	ND	8.000	UGL	[illegible].000
CGW	WELL	MI058	ENDRNK	02/02/92	XDV	003	0.000	ND	8.000	UGL	[illegible]00
CGW	WELL	MI058	ENDRNK	02/02/92	XDV	004	0.000	ND	8.000	UGL	0.000
CGW	WELL	MI058	ESFSO4	02/02/92	XDV	003	0.000	ND	9.200	UGL	0.000
CGW	WELL	MI058	ESFSO4	02/02/92	XDV	004	0.000	ND	9.200	UGL	0.000
CGW	WELL	MI058	ETC6H5	02/02/92	XLS	012	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI058	ETC6H5	02/02/92	XLT	012	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI058	FANT	02/02/92	XDV	003	0.000	LT	3.300	UGL	0.000
CGW	WELL	M'058	FANT	02/02/92	XDV	004	0.000	LT	3.300	UGL	0.000
CGW	WELL	MI058	FE	02/02/92	WZS	020	0.000		60.200	UGL	0.000
CGW	WELL	MI058	FE	02/02/92	WZS	021	0.000		86.600	UGL	0.000
CGW	WELL	MI058	FE	02/02/92	WZS	027	0.000		48.800	UGL	0.000
CGW	WELL	MI058	FE	02/02/92	WZS	028	0.000		81.700	UGL	0.000
CGW	WELL	MI058	FLRENE	02/02/92	XDV	003	0.000	LT	3.700	UGL	0.000
CGW	WELL	MI058	FLRENE	02/02/92	XDV	004	0.000	LT	3.700	UGL	0.000
CGW	WELL	MI058	GCLDAN	02/02/92	XDV	003	0.000	ND	5.100	UGL	0.000
CGW	WELL	MI058	GCLDAN	02/02/92	XDV	004	0.000	ND	5.100	UGL	0.00[illegible]
CGW	WELL	MI058	HCBD	02/02/92	XDV	003	0.000	LT	3.400	UGL	0.000
CGW	WELL	MI058	HCBD	02/02/92	XDV	004	0.000	LT	3.400	UGL	0.000
CGW	WELL	MI058	HG	02/02/92	XCS	019	0.000	LT	0.243	UGL	0.000
CGW	WELL	MI058	HG	02/02/92	XCS	020	0.000		0.251	UGL	0.000
CGW	WELL	MI058	HG	02/02/92	XCS	026	0.000	LT	0.243	UGL	0.000
CGW	WELL	MI058	HG	02/02/92	XCS	027	0.000	LT	0.243	UGL	0.000
CGW	WELL	MI058	HMX	02/02/92	XKP	008	0.000		1100.000	UGL	0.000

Media	Site Type	Site ID	Analyte	Sample Date	Sample Lot	Number	Depth	Boolean	Value	Unit	Percent Moisture
CGW	WELL	MI058	NI	02/02/92	WZS	027	0.000	LT	34.300	UGL	0.000
CGW	WELL	MI058	NI	02/02/92	WZS	028	0.000	LT	34.300	UGL	0.000
CGW	WELL	MI058	NNDMEA	02/02/92	XDV	003	0.000	ND	2.000	UGL	0.000
CGW	WELL	MI058	NNDMEA	02/02/92	XDV	004	0.000	ND	2.000	UGL	0.000
CGW	WELL	MI058	NNDNPA	02/02/92	XDV	003	0.000	LT	4.400	UGL	0.000
CGW	WELL	MI058	NNDNPA	02/02/92	XDV	004	0.000	LT	4.400	UGL	0.000
CGW	WELL	MI058	NNDPA	02/02/92	XDV	003	0.000	LT	3.000	UGL	0.000
CGW	WELL	MI058	NNDPA	02/02/92	XDV	004	0.000	LT	3.000	UGL	0.000
CGW	WELL	MI058	PB	02/02/92	XWD	017	0.000	LT	1.260	UGL	0.000
CGW	WELL	MI058	PB	02/02/92	XWD	018	0.000	LT	1.260	UGL	0.000
CGW	WELL	MI058	PB	02/02/92	XWD	024	0.000	LT	1.260	UGL	0.000
CGW	WELL	MI058	PB	02/02/92	XWD	025	0.000	LT	1.260	UGL	0.000
CGW	WELL	MI058	PCB016	02/02/92	XDV	003	0.000	ND	21.000	UGL	0.000
CGW	WELL	MI058	PCB016	02/02/92	XDV	004	0.000	ND	21.000	UGL	0.000
CGW	WELL	MI058	PCB221	02/02/92	XDV	003	0.000	ND	21.000	UGL	0.000
CGW	WELL	MI058	PCB221	02/02/92	XDV	004	0.000	ND	21.000	UGL	0.000
CGW	WELL	MI058	PCB232	02/02/92	XDV	003	0.000	ND	21.000	UGL	0.000
CGW	WELL	MI058	PCB232	02/02/92	XDV	004	0.000	ND	21.000	UGL	0.000
CGW	WELL	MI058	PCB242	02/02/92	XDV	003	0.000	ND	30.000	UGL	0.000
CGW	WELL	MI058	PCB242	02/02/92	XDV	004	0.000	ND	30.000	UGL	0.000
CGW	WELL	MI058	PCB248	02/02/92	XDV	003	0.000	ND	30.000	UGL	0.000
CGW	WELL	MI058	PCB248	02/02/92	XDV	004	0.000	ND	30.000	UGL	0.000
CGW	WELL	MI058	PCB254	02/02/92	XDV	003	0.000	ND	36.000	UGL	0.000
CGW	WELL	MI058	PCB254	02/02/92	XDV	004	0.000	ND	36.000	UGL	0.000
CGW	WELL	MI058	PCB260	02/02/92	XDV	003	0.000	ND	36.000	UGL	0.000
CGW	WELL	MI058	PCB260	02/02/92	XDV	004	0.000	ND	36.000	UGL	0.000
CGW	WELL	MI058	PCP	02/02/92	XDV	003	0.000	LT	18.000	UGL	0.000
CGW	WELL	MI058	PCP	02/02/92	XDV	004	0.000	LT	18.000	UGL	0.000
CGW	WELL	MI058	PETN	02/02/92	XZB	006	0.000	LT	20.000	UGL	0.000
CGW	WELL	MI058	PETN	02/02/92	XZB	007	0.000	LT	20.000	UGL	0.000
CGW	WELL	MI058	PHANTR	02/02/92	XDV	003	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI058	PHANTR	02/02/92	XDV	004	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI058	PHENOL	02/02/92	XDV	003	0.000	LT	9.200	UGL	0.000
CGW	WELL	MI058	PHENOL	02/02/92	XDV	004	0.000	LT	9.200	UGL	0.000
CGW	WELL	MI058	PPDDD	02/02/92	XDV	003	0.000	ND	4.000	UGL	0.000
CGW	WELL	MI058	PPDDD	02/02/92	XDV	004	0.000	ND	4.000	UGL	0.000
CGW	WELL	MI058	PPDDE	02/02/92	XDV	003	0.000	ND	4.700	UGL	0.000
CGW	WELL	MI058	PPDDE	02/02/92	XDV	004	0.000	ND	4.700	UGL	0.000
CGW	WELL	MI058	PPDDT	02/02/92	XDV	003	0.000	ND	9.200	UGL	0.000
CGW	WELL	MI058	PPDDT	02/02/92	XDV	004	0.000	ND	9.200	UGL	0.000
CGW	WELL	MI058	PYR	02/02/92	XDV	003	0.000	LT	2.800	UGL	0.000
CGW	WELL	MI058	PYR	02/02/92	XDV	004	0.000	LT	2.800	UGL	0.000
CGW	WELL	MI058	RDX	02/02/92	XKP	008	0.000		5600.000	UGL	0.000
CGW	WELL	MI058	RDX	02/02/92	XKP	009	0.000		10000.000	UGL	0.000
CGW	WELL	MI058	SB	02/02/92	WZS	020	0.000	LT	38.000	UGL	0.000
CGW	WELL	MI058	SB	02/02/92	WZS	021	0.000	LT	38.000	UGL	0.000
CGW	WELL	MI058	SB	02/02/92	WZS	027	0.000	LT	38.000	UGL	0.000

Media	Site Type	Site ID	Analyte	Sample Date	Sample Lot Number	Depth	Boolean	Value	Unit	Percent Moisture
CGW	WELL	MI058	SB	02/02/92	WZS 028	0.000	LT	38.000	UGL	0.000
CGW	WELL	MI058	SE	02/02/92	XTI 019	0.000	LT	3.020	UGL	0.000
CGW	WELL	MI058	SE	02/02/92	XTI 020	0.000	LT	3.020	UGL	0.000
CGW	WELL	MI058	SE	02/02/92	XTI 024	0.000	LT	3.020	UGL	0.000
CGW	WELL	MI058	SE	02/02/92	XTI 025	0.000	LT	3.020	UGL	0.000
CGW	WELL	MI058	STYR	02/02/92	XLS 012	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI058	STYR	02/02/92	XLT 012	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI058	T13DCP	02/02/92	XLS 012	0.000	LT	0.700	UGL	0.000
CGW	WELL	MI058	T13DCP	02/02/92	XLT 012	0.000	LT	0.700	UGL	0.000
CGW	WELL	MI058	TCLEA	02/02/92	XDV 003	0.000		7.000	UGL	0.000
CGW	WELL	MI058	TCLEA	02/02/92	XLS 012	0.000	LT	0.510	UGL	0.000
CGW	WELL	MI058	TCLEA	02/02/92	XLT 012	0.000	LT	0.510	UGL	0.000
CGW	WELL	MI058	TCLEE	02/02/92	XLS 012	0.000	LT	1.600	UGL	0.000
CGW	WELL	MI058	TCLEE	02/02/92	XLT 012	0.000	LT	1.500	UGL	0.000
CGW	WELL	MI058	TETRYL	02/02/92	XKP 008	0.000	LT	2.490	UGL	0.000
CGW	WELL	MI058	TETRYL	02/02/92	XKP 009	0.000	LT	2.490	UGL	0.000
CGW	WELL	MI058	TL	02/02/92	WZS 020	0.000	LT	81.400	UGL	0.000
CGW	WELL	MI058	TL	02/02/92	WZS 021	0.000	LT	81.400	UGL	0.000
CGW	WELL	MI058	TL	02/02/92	WZS 027	0.000	LT	81.400	UGL	0.000
CGW	WELL	MI058	TL	02/02/92	WZS 028	0.000	LT	81.400	UGL	0.000
CGW	WELL	MI058	TRCLE	02/02/92	XLS 012	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI058	TRCLE	02/02/92	XLT 012	0.000	LT	0.500	UGL	0.000
CGW	WELL	MI058	TXPHEN	02/02/92	XDV 003	0.000	ND	36.000	UGL	0.000
CGW	WELL	MI058	TXPHEN	02/02/92	XDV 004	0.000	ND	36.000	UGL	0.000
CGW	WELL	MI058	UNK551	02/02/92	XDV 003	0.000		10.000	UGL	0.000
CGW	WELL	MI058	UNK551	02/02/92	XDV 004	0.000		10.000	UGL	0.000
CGW	WELL	MI058	UNK578	02/02/92	XDV 003	0.000		40.000	UGL	0.000
CGW	WELL	MI058	UNK578	02/02/92	XDV 004	0.000		40.000	UGL	0.000
CGW	WELL	MI058	UNK585	02/02/92	XDV 003	0.000		9.000	UGL	0.000
CGW	WELL	MI058	UNK585	02/02/92	XDV 004	0.000		9.000	UGL	0.000
CGW	WELL	MI058	UNK595	02/02/92	XDV 003	0.000		2000.000	UGL	0.000
CGW	WELL	MI058	UNK595	02/02/92	XDV 004	0.000		2000.000	UGL	0.000
CGW	WELL	MI058	UNK604	02/02/92	XDV 003	0.000		40.000	UGL	0.000
CGW	WELL	MI058	UNK604	02/02/92	XDV 004	0.000		40.000	UGL	0.000
CGW	WELL	MI058	UNK607	02/02/92	XDV 003	0.000		90.000	UGL	0.000
CGW	WELL	MI058	UNK607	02/02/92	XDV 004	0.000		100.000	UGL	0.000
CGW	WELL	MI058	V	02/02/92	WZS 020	0.000	LT	11.000	UGL	0.000
CGW	WELL	MI058	V	02/02/92	WZS 021	0.000	LT	11.000	UGL	0.000
CGW	WELL	MI058	V	02/02/92	WZS 027	0.000	LT	11.000	UGL	0.000
CGW	WELL	MI058	V	02/02/92	WZS 028	0.000	LT	11.000	UGL	0.000
CGW	WELL	MI058	XYLEN	02/02/92	XLS 012	0.000	LT	0.840	UGL	0.000
CGW	WELL	MI058	XYLEN	02/02/92	XLT 012	0.000	LT	0.840	UGL	0.000
CGW	WELL	MI058	ZN	02/02/92	WZS 020	0.000		37.400	UGL	0.000
CGW	WELL	MI058	ZN	02/02/92	WZS 021	0.000		31.400	UGL	0.000
CGW	WELL	MI058	ZN	02/02/92	WZS 027	0.000		37.100	UGL	0.000
CGW	WELL	MI058	ZN	02/02/92	WZS 028	0.000		42.900	UGL	0.000
CGW	WELL	S-99	CYN	01/21/92	VWI 006	0.000	LT	2.500	UGL	0.000

Media	Site Type	Site ID	Analyte	Sample Date	Lot	Sample Number	Depth	Boolean	Value	Unit	Percent Moisture
CSO	BORE	SB-1	111TCE	01/30/92	XQJ	003	47.000	LT	0.022	UGG	13.600
CSO	BORE	SB-1	111TCE	01/30/92	XQK	002	14.500	LT	0.022	UGG	19.000
CSO	BORE	SB-1	112TCE	01/30/92	XQJ	003	47.000	LT	0.027	UGG	13.600
CSO	BORE	SB-1	112TCE	01/30/92	XQK	002	14.500	LT	0.027	UGG	19.000
CSO	BORE	SB-1	11DCE	01/30/92	XQJ	003	47.000	LT	0.020	UGG	13.600
CSO	BORE	SB-1	11DCE	01/30/92	XQK	002	14.500	LT	0.020	UGG	19.000
CSO	BORE	SB-1	11DCLE	01/30/92	XQJ	003	47.000	LT	0.011	UGG	13.600
CSO	BORE	SB-1	11DCLE	01/30/92	XQK	002	14.500	LT	0.011	UGG	19.000
CSO	BORE	SB-1	124TCB	01/30/92	WXQ	005	14.500	LT	0.040	UGG	19.000
CSO	BORE	SB-1	124TCB	01/30/92	WXR	002	47.000	LT	0.040	UGG	13.600
CSO	BORE	SB-1	12DCE	01/30/92	XQJ	003	47.000	LT	0.015	UGG	13.600
CSO	BORE	SB-1	12DCE	01/30/92	XQK	002	14.500	LT	0.015	UGG	19.000
CSO	BORE	SB-1	12DCLB	01/30/92	WXQ	005	14.500	LT	0.110	UGG	19.000
CSO	BORE	SB-1	12DCLB	01/30/92	WXR	002	47.000	LT	0.110	UGG	13.600
CSO	BORE	SB-1	12DCLE	01/30/92	XQJ	003	47.000	LT	0.008	UGG	13.600
CSO	BORE	SB-1	12DCLE	01/30/92	XQK	002	14.500	LT	0.008	UGG	19.000
CSO	BORE	SB-1	12DCLP	01/30/92	XQJ	003	47.000	LT	0.015	UGG	13.600
CSO	BORE	SB-1	12DCLP	01/30/92	XQK	002	14.500	LT	0.015	UGG	19.000
CSO	BORE	SB-1	12DPH	01/30/92	WXQ	005	14.500	ND	0.140	UGG	19.000
CSO	BORE	SB-1	12DPH	01/30/92	WXR	002	47.000	ND	0.140	UGG	13.600
CSO	BORE	SB-1	135TNB	01/30/92	XFZ	021	14.500		7.240	UGG	1.500
CSO	BORE	SB-1	135TNB	01/30/92	XFZ	022	17.000		7.510	UGG	1.600
CSO	BORE	SB-1	135TNB	01/30/92	XFZ	023	22.000		0.841	UGG	0.300
CSO	BORE	SB-1	135TNB	01/30/92	XFZ	024	22.000		0.546	UGG	0.200
CSO	BORE	SB-1	135TNB	01/30/92	XFZ	025	27.000	LT	0.488	UGG	0.200
CSO	BORE	SB-1	135TNB	01/30/92	XFZ	026	32.000	LT	0.488	UGG	0.100
CSO	BORE	SB-1	135TNB	01/30/92	XFZ	027	37.000		0.875	UGG	0.800
CSO	BORE	SB-1	135TNB	01/30/92	XFZ	028	42.000		1.020	UGG	0.900
CSO	BORE	SB-1	135TNB	01/30/92	XFZ	029	47.000		1.920	UGG	0.400
CSO	BORE	SB-1	13DCLB	01/30/92	WXQ	005	14.500	LT	0.130	UGG	19.000
CSO	BORE	SB-1	13DCLB	01/30/92	WXR	002	47.000	LT	0.130	UGG	13.600
CSO	BORE	SB-1	13DNB	01/30/92	XFZ	021	14.500	LT	0.496	UGG	1.500
CSO	BORE	SB-1	13DNB	01/30/92	XFZ	022	17.000	LT	0.496	UGG	1.600
CSO	BORE	SB-1	13DNB	01/30/92	XFZ	023	22.000	LT	0.496	UGG	0.300
CSO	BORE	SB-1	13DNB	01/30/92	XFZ	024	22.000	LT	0.496	UGG	0.200
CSO	BORE	SB-1	13DNB	01/30/92	XFZ	025	27.000	LT	0.496	UGG	0.200
CSO	BORE	SB-1	13DNB	01/30/92	XFZ	026	32.000	LT	0.496	UGG	0.100
CSO	BORE	SB-1	13DNB	01/30/92	XFZ	027	37.000	LT	0.496	UGG	0.800
CSO	BORE	SB-1	13DNB	01/30/92	XFZ	028	42.000	LT	0.496	UGG	0.900
CSO	BORE	SB-1	13DNB	01/30/92	XFZ	029	47.000	LT	0.496	UGG	0.400
CSO	BORE	SB-1	14DCLB	01/30/92	WXQ	005	14.500	LT	0.098	UGG	19.000
CSO	BORE	SB-1	14DCLB	01/30/92	WXR	002	47.000	LT	0.098	UGG	13.600
CSO	BORE	SB-1	245TCP	01/30/92	WXQ	005	14.500	LT	0.100	UGG	19.000
CSO	BORE	SB-1	245TCP	01/30/92	WXR	002	47.000	LT	0.100	UGG	13.600
CSO	BORE	SB-1	246TCP	01/30/92	WXQ	005	14.500	LT	0.170	UGG	19.000
CSO	BORE	SB-1	246TCP	01/30/92	WXR	002	47.000	LT	0.170	UGG	13.600
CSO	BORE	SB-1	246TNT	01/30/92	XFZ	021	14.500		12.800	UGG	1.500

APPENDIX C

CALCULATION SHEETS FOR COST ESTIMATES

ICF KAISER ENGINEERS

JOB No

SHEET 1 OF 1

DESIGNED BY M DATE

CHECKED BY MCM DATE 3

EXTRACTION SYSTEM COSTS
EXTRACTION WELLS

INSTALLATION OF NEW WELLS

Assume
shallow well : screened 75-125 ft

submersible pump will be placed @ top of screen

Cost of Extraction Well (Ea)

Shallow : $90/ft x 125 ft = $11,250

ALTERNATIVE	# OF SHALLOW WELLS	# OF DEEP WELLS	Total Price of Wells
E-1	6	0	$67,500

Source : Estimate based on prior quotations from drilling company.

CALCULATIONS KE Form No E-6 Rev 12-89

ICF KAISER ENGINEERS

JOB No
SHEET 1 OF 1

EXTRACTION SYSTEM COSTS
SUBMERSIBLE PUMPS

DESIGNED BY MS DATE
CHECKED BY MCM DATE 3.

Submersible pumps

shallow: Grundfos Model # 80330-3
Performance 100gpm @ 80'TDH
3HP, 3phase, 60HZ motor
Price: $1,699 ea

(pumps include costs for magnetic starter w/ heaters)

ALTERNATIVE	# OF SHALLOW PUMPS	# OF DEEPWELL PUMPS	TOTAL PRICE OF PUMPS
E-1	6	0	$10,194

CALCULATIONS KE Form No E-6 Rev 12 89

ICF KAISER ENGINEERS

JOB No ______
SHEET 1 OF 1

EXTRACTION SYSTEM COSTS
OPERATION + MAINTENANCE

DESIGNED BY NNA DATE
CHECKED BY MCM DATE 3.

Annual
O+M Costs

$ 3

- Assume pump maintenance of $200/yr/pump

$\Rightarrow \frac{\$200/yr}{pump} \times 6 \text{ pumps} = \$1200/yr$

- Pump Electrical Use

ALTERNATIVE E-1 (6 shallow well, 3HP)

$3\ HP \times 0.7457 \frac{KW}{HP} = 2.23\ KW$ Power

$2.23\ KW \left(24\ hr/day\right)\left(\frac{365\ day}{yr}\right)\left(\$0.10/KW\right) = \$1959/yr/pump$

$\frac{\$1959/yr}{pump} \times 6 = 11,758 \Longrightarrow \$12,000$

1200
12,000
$13,200/yr

↓

$13,000/yr

CALCULATIONS KE Form No E-6 Rev 12 89

ICF KAISER ENGINEERS

JOB No ______

SHEET 1 OF 1

DESIGNED BY NNA DATE

CHECKED BY MCM DATE 3.

EXTRACTION SYSTEM COSTS
OPERATION + MAINTENANCE

Annual
O+M Costs

$ 13,

- Assume pump maintenance of $200/yr/pump

$$\Rightarrow \frac{\$200/yr}{pump} \times 6 \text{ pumps} = \$1200/yr$$

- Pump Electrical Use

ALTERNATIVE E-1 (6 shallow well, 3HP)

$$3\ HP \times 0.7457 \frac{KW}{HP} = 2.23\ KW \quad \text{Power}$$

$$2.23\ KW \left(\frac{24\ hr}{day}\right)\left(\frac{365\ day}{yr}\right)\left(\frac{\$0.10}{KW}\right) = \$1959/yr/pump$$

$$\frac{\$1959/yr}{pump} \times 6 = 11,758 \Rightarrow \$12,000$$

1200
12,000
$ 13,200 /yr
↓
$ 13,000 /yr

CALCULATIONS KE Form No E-6 Rev 12-89

ICF KAISER ENGINEERS

JOB No C-3C?-?C??
SHEET 1 OF 2

MILAN ARMY AMMUNITION PLANT
GENERAL ACTIONS / SITE PREPARATION

DESIGNED BY NNA DATE 3
CHECKED BY MCM DATE 3

II. GENERAL ACTIONS / SITE PREPARATION

1.) Parking / Staging Area — $ 1C

- Staging area required for ion exchange equipment and parking
- assume 30' x 40' staging area
- 8" deep gravel, spread and compacted @ $6.50/yd²

staging area = 30' x 40' = 1200 ft²

$\Rightarrow$ 1200 ft² $\times \left(\frac{1\ yd}{3\ ft}\right)^2$ = 133.3 yd²

$\Rightarrow$ 133.3 yd² $\times$ $6.50/yd² = $867 ≈ 1000

2. Treatment System Building Construction — $ 15C

- assume building is 7500 SQ FT
- Houses pre-treatment system, UV-oxidation unit or carbon adsorption unit
- assume building is constructed with prefabricated steel, insulated, 6" slab concrete base with plumbing and electricity.
- Costs are based on square footage of the building.

Basic building 26 guage galvanized pre-fabricated steel	$ 9.25/FT²
6" slab concrete base	$ 2.00/FT²
Plumbing	$ 2.60/FT²
Electrical	$ 3.75/FT²
R-20 Insulation	$ 2.45/FT²
	$20.05/FT²

7500 FT² $\times$ $20.05/FT² = $150,375 ≈

Source: Means, Mechanical, 1989
Means site, 1991

ICF KAISER ENGINEERS

JOB NO [illegible]

SHEET 2 OF 2

MILAN ARMY AMMUNITION PLANT
GENERAL ACTIONS SITE PREPARATION

DESIGNED BY NNA DATE 3

CHECKED BY MCM DATE 3.1

3. Building Lighting and Heating

a.) Capital Costs $35,

i) Lighting

- assume 8' Fluorescent lights @ $690 / light
- 7500 FT² BLDG AREA / 300 FT² AREA PER LIGHT = 25 Lights required
- $690/Light x 25 Lights = $17,250

ii) Heating and Ventilation

- Heating and Ventilating @ $2.39/FT²

7500 FT² x $2.39/FT² = $17,925

$35,175

b.) Annual O+M Costs $70

- No annual costs for heating. Heating will be supplied by on-site steam generator
- Per Potomac Electric Power Co.

Average Usage for Industrial Site – 1.5W/FT²
– $0.07 /KW Hr

1.5W/FT² X 7500 FT² x 1KW / 1000 W
x $.07 / KW Hr x 24 Hr/day · 365 day/yr
= $6899

Sources: Means Mechanical, 1989
Means Site, 1991

CALCULATIONS KE Form No E 6 Rev 12 89

022 | Earthwork

022 300 | Pavement Base

			CREW	DAILY OUTPUT	MAN-HOURS	UNIT	BARE COSTS MAT.	LABOR	EQUIP	TOTAL	TC INC
308	0300	12" deep	B-36	2,350	.017	S.Y.	8.55	.34	43	9 32	
	0301	Crushed 1-½" stone base, compacted to 4" deep		5,225	.008		2.58	.15	.20	2 93	
	0302	6" deep		3,900	.010		3.90	.20	.26	4 36	
	0303	8" deep		3,000	.013		5.19	.27	34	5 80	
	0304	12" deep		1,800	.022		7.80	.44	.57	8.81	
	0350	Bank run gravel, spread and compacted									
	0370	6" deep	B-32	6,000	.005	S.Y.	1.54	.11	.25	1 90	
	0390	9" deep		44,000	.001		2.31	.02	.03	2 36	
	0400	12" deep		3,600	.009		3.08	.19	.41	3.68	
	0500	Bituminous concrete, 4" thick	B-25	4,545	.019		6.70	.37	.33	7 40	
	0550	6" thick		3,700	.024		10.05	.45	.41	10.91	
	0560	8" thick		3,000	.029		13.45	.56	.50	14.51	
	0570	10" thick		2,545	.035		16.75	.66	.59	18	
	0600	Cold laid asphalt pavement, see div. 025-116									
	0700	Liquid application to gravel base, asphalt emulsion	B-45	6,000	.003	Gal.	1.24	.05	.10	1.39	
	0800	Prime and seal, cut back asphalt		6,000	.003		1.44	.05	.10	1.59	
	1000	Macadam penetration crushed stone, 2 gal. per S.Y., 4" thick		6,000	.003	S.Y.	2.50	.05	.10	2.65	
	1100	6" thick, 3 gal. per S.Y.		4,000	.004		3.65	.08	.16	3 89	
	1200	8" thick, 4 gal. per S.Y.		3,000	.005		5	.11	.21	5.32	
	1500	Alternate method to figure base course									
	1510	Crushed stone, ¾" maximum size, 3" deep	B-36	435	.092	C.Y.	25.80	1.83	2.35	29 98	
	1511	6" deep		1,305	.031		25.80	.61	78	27 19	
	1512	9" deep		1,435	.028		25.80	.55	.71	27.06	
	1513	12" deep		1,565	.026		25.80	.51	.65	26.96	
	1520	Crushed stone, 1-½" maximum size, 4" deep		580	.069		24.45	1.37	1.76	27.58	
	1521	6" deep		650	.062		24.45	1.22	1.57	27.24	
	1522	8" deep		665	.060		24.45	1.20	1.54	27.19	
	1523	12" deep		785	.051		24.45	1.01	1.30	26.76	
	1530	Gravel, bank run, 6" deep	B-32A	650	.037		9.25	.77	1.33	11.35	
	1531	9" deep		720	.033		9.25	.69	1.20	11 14	
	1532	12" deep		785	.031		9.25	.64	1.10	10.99	
	2000	Alternate method to figure base course									
	2005	Bituminous concrete, 4" thick	B-25	1,000	.088	Ton	28.80	1.68	1.51	31.99	
	2006	6" thick		1,220	.072		28.80	1.37	1.24	31.41	
	2007	8" thick		1,320	.067		28.80	1.27	1.14	31.21	
	2008	10" thick		1,400	.063		28.80	1.20	1.08	31.08	
	2010	Crushed stone, ¾" maximum size, 3" deep	B-36	540	.074		13.45	1.47	1.89	16.81	
	2011	6" deep		1,625	.025		13.45	.49	.63	14.57	
	2012	9" deep		1,785	.022		13.45	.45	.57	14.47	
	2013	12" deep		1,950	.021		13.45	.41	.52	14.38	
	2020	Crushed stone, 1-½" maximum size, 4" deep		720	.056		12.85	1.11	1.42	15.38	
	2021	6" deep		815	.049		12.85	.98	1.25	15.08	
	2022	8" deep		835	.048		12.85	.95	1.22	15.02	
	2023	12" deep		975	.041		12.85	.82	1.05	14.72	
	2030	Bank run gravel, 6" deep	B-32A	675	.027		6.95	.57	.99	8.51	
	2031	9" deep		970	.025		6.95	.52	.89	8.36	
	2032	12" deep		1,060	.023		6.95	.47	.81	8.23	
	6000	Stabilization fabric, polypropylene, 6 oz./S.Y.	B-6	10,000	.002	S.Y.	1.42	.05	.02	1.49	
	8900	For small and irregular areas, add						50%	50%		

022 400 | Soil Stabilization

			CREW	DAILY OUTPUT	MAN-HOURS	UNIT	MAT.	LABOR	EQUIP	TOTAL
408	0010	GROUTING, PRESSURE Cement and sand, 1:1 mix, minimum	B-61	124	.323	Bag	6.80	6.05	2.55	15.40
	0100	Maximum		51	.784		7.80	14.65	6.20	28.65
	0200	Cement and sand, 1:1 mix, minimum		250	.160	C.F.	4.55	2.99	1.28	8.80
	0300	Maximum		100	.400		6	7.45	3.16	16.61
	0400	Cement grout, minimum (1 bag = 1 C.F.)		137	.292		6.30	5.45	2.31	14.06
	0500	Maximum		57	.702		7.45	13.10	5.55	26.10

(74) Pre-engineered Steel Buildings (Div. 051-235)

These buildings are manufactured by many companies and normally erected by franchised dealers throughout the U.S. The four basic types are: Rigid Frames, Truss type, Post and Beam and the Sloped Beam type. Most popular roof slope is low pitch of 1" in 12". The minimum economical area of these buildings is about 3000 S.F. of floor area. Bay sizes are usually 20' to 24' but can go as high as 30' with heavier girts and purlins. Eave heights are usually 12' to 24' with 18' to 20' most typical. Pre-engineered buildings become increasingly economical with higher eave heights.

Prices shown here are for the building shell only and do not include floors, foundations, interior finishes or utilities. Erection of the frame and insulated roof runs $1.05 to $1.35 per S.F. Insulated side wall installation runs about $1.10 per S.F. of skin. Typical erection cost including both siding and roofing depends on the building shape and runs $1 30 to $2 50 for on roof slope and $1.35 to $3.50 per S F of floor for fou roof slope. Site, weather, labor source, shape and siz will determine the erection cost of each job Prices ir erector's overhead and profit.

Table below is based on 30 psf roof load, 20 psf winc no unusual structural requirements. Costs assume a bays of 24' each. Material costs include the structura ga. colored steel roofing, 26 ga. colored steel siding, closures and flashing but no allowance for doors, wi gutters or skylights. Very large projects would gener than the prices listed below. Typical budget figures f material delivered to the job runs $1190 to $1420 per Fasteners and flashings (included below) run $.45 to

Material Costs per S.F. of Floor Area Above the Foundations					
Type of Building	Total Width in Feet	Eave Height			
		10 Ft.	14 Ft.	16 Ft.	20 Ft.
Rigid Frame Clear Span	30-40	$3.45	$3.75	$4.05	$4 45
	50-100	3.50	3.55	3.85	4 05
	110	—	—	—	—
	120	—	—	—	3 80
	130	—	—	—	—
Tapered Beam Clear Span	30	3.70	4.10	4.50	4 80
	40	3.40	3.65	3.90	4 35
	50-80	3.30	3.45	3.65	3.90
Post & Beam 1 Post at Center	80	—	3.00	3.30	3.50
	100	—	2.90	3.10	3.45
	120	—	2.85	2.95	3.15
Post & Beam 2 Posts at 1/3 Points	120	—	—	—	—
	150	—	2.90	3.10	3.30
	180	—	—	—	—
Post & Beam 3 Posts at 1/4 points	160	—	2.85	2.95	3.30
	200	—	2.90	3.10	3.35
	240	—	—	—	—

Typical accessory items are listed in the front of the book. All normal interior work, floors, foundations, utilities and sitework should be figured the same as usual.

Costs in the table below include allowance for erect doors, windows, gutters and erector's overhead and Figures do not include foundations, floors, interior fi electrical, mechanical or installed equipment.

Total Cost per S.F. Above the Foundations, 16' Eave Height			Add to Basic Building Price	
Project Size: Rigid Frame 30' to 60' Spans 1 in 12 Roof Slope	Basic Building Using 26 ga. Galvanized Roof & Siding	R20 Field Insulation	Exterior Finish	S.F. c
	S.F. Floor Area	S.F. Floor Area	Sandwich wall	$3 00
			Vinyl clad steel	-
4,000 S.F.	$5.30	$2.45	Corrugated fiberglass	1
10,000 S.F.	4.65	1.95	Corr. fiberglass-insulated	1
20,000 S.F.	4.30	1.80	20 year paint	

051 200 | Structural Steel

			CREW	DAILY OUTPUT	MAN-HOURS	UNIT	BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL
220	1100	For galvanizing, add				Lb	.40			.40	
	1500	Steel pipe, extra strong, no concrete, 3" to 5" O.D.	E-2	12.960	.004		.80	.10	.08	.98	
	1600	6" to 12" O.D.		39.100	.001		.70	.03	.03	.76	
	3300	Square structural tubing, 4" to 6" square, light section		11.270	.005		.75	.12	.10	.97	
	3600	Heavy section		27.600	.002		.70	.05	.04	.79	
	5100	Rectangular structural tubing, 5" to 6" wide, light section		9.500	.006		.85	.14	.11	1.10	
	5200	Heavy section		31.200	.002		.80	.04	.03	.87	
	5300	7" to 10" wide, light section		37.000	.002		.78	.04	.03	.85	
	5400	Heavy section		68.000	.001		.75	.02	.02	.79	
	5800	Adjustable jack post, 8' maximum height, 2-3/4" diameter				Ea.	17.50			17.50	
	5850	4" diameter					28.50			28.50	
	6800	Wide flange, A36 steel, 2 tier, W 8 x 24	E-2	1,080	.052	L.F.	13	1.22	.99	15.21	
	6900	W 8 x 48		1,032	.054		25	1.28	1.04	27.32	
	7050	W 10 x 68		984	.057		36	1.34	1.09	38.43	
	7100	W 10 x 112		960	.058		59	1.38	1.12	61.50	
	7200	W 12 x 87		984	.057		46	1.34	1.09	48.43	
	7250	W 12 x 120		960	.058		63	1.38	1.12	65.50	
	7350	W 14 x 74		984	.057		39	1.34	1.09	41.43	
	7450	W 14 x 176		912	.061		92	1.45	1.17	94.62	
230	0011	LIGHTWEIGHT FRAMING									
	0400	Angle framing, 4" and larger	E-4	3.000	.011	Lb	.72	.26	.02	1	
	0450	Less than 4" angles		1,800	.018		.75	.44	.04	1.23	
	0600	Channel framing, 8" and larger		3,500	.009		.75	.22	.02	.99	
	0650	Less than 8" channels		2,000	.016		.78	.39	.03	1.20	
	1000	Continuous slotted channel framing system, minimum	2 Sswk	2,400	.007		1.15	.16		1.31	
	1200	Maximum		1,600	.010		2	.24		2.24	
	1300	Cross bracing, rods, 3/4" diameter	E-3	700	.034		.80	.85	.19	1.84	
	1310	7/8" diameter		700	.034		.68	.85	.19	1.72	
	1320	1" diameter		700	.034		.68	.85	.19	1.72	
	1330	Angle, 5" x 5" x 3/8"		2,800	.009		.72	.21	.05	.98	
	1350	Hanging lintels, average		850	.028		.75	.70	.15	1.60	
	1380	Roof frames, 3'-0" square, 5' span	E-2	4,200	.013		.68	.31	.26	1.25	
	1400	Tie rod, not upset, 1-1/2" to 4" diameter, with turnbuckle	2 Sswk	800	.020		.75	.48		1.23	
	1420	No turnbuckle		700	.023		.68	.55		1.23	
	1500	Upset, 1-3/4" to 4" diameter, with turnbuckle		800	.020		.85	.48		1.33	
	1520	No turnbuckle		700	.023		.75	.55		1.30	
232	0010	LINTELS Plain steel angles, under 500 lb.	1 Bric	500	.016	Lb.	.50	.36		.86	
	0100	500 to 1000 lb.		600	.013		.46	.30		.76	
	0200	1000 to 2000 lb.		600	.013		.42	.30		.72	
	0300	2000 to 4000 lb.		600	.013		.40	.30		.70	
	0500	For built-up angles and plates, add to above					.50			.50	
	0700	For engineering, add to above					.12			.12	
	0900	For galvanizing, add to above, under 500 lb.					.38			.38	
	1000	Over 2000 lb.					.28			.28	
	2000	Steel angles, 3-1/2" x 3", 1/4" thick, 2'-6" long	1 Bric	50	.160	Ea.	6.75	3.64		10.39	
	2100	4'-6" long		45	.178		12.15	4.04		16.19	
	2600	4" x 3-1/2", 1/4" thick, 5'-0" long		40	.200		15.50	4.55		20.05	
	2700	9'-0" long		35	.229		27.90	5.20		33.10	
	3500	For precast concrete lintels, see div. 034-802									
235	0010	PRE-ENGINEERED STEEL BUILDINGS For Hangars see div. 131-211									
	0100	Building shell above the foundations with 26 ga. colored									
	0110	Roofing and siding, minimum 74	E-2	1,800	.031	SF Flr.	2.85	.73	.60	4.18	
	0200	Maximum		1,000	.056		5.30	1.32	1.07	7.69	
250	0010	STRUCTURAL STEEL MEMBERS Common WF sizes, spans 10' to 45'									
	0020	including bolted connections and erection									

033 | Cast-In-Place Concrete

033 100 Structural Concrete		CREW	DAILY OUTPUT	MAN-HOURS	UNIT	BARE COSTS MAT.	LABOR	EQUIP	TOTAL	TOTAL INCL O&P
126 3400	Black, 1.8 lb. per bag, add				C.Y.	12.75			12.75	14.05
3500	7.5 lb. per bag, add					53			53	58
3700	Green, 1.8 lb. per bag, add					25			25	28
3800	7.5 lb. per bag, add					105			105	115
130 0010	CONCRETE IN PLACE including forms (4 uses), reinforcing									
0130	Average for substructure only, simple design, incl. finishing	C-17B	29.07	2.820	C.Y.	75.70	65	9.85	150.55	195
0200	Base, granolithic, 1" x 5" high, straight	C-10	175	.137	L.F.	.13	2.78	.40	3.31	4.70
0220	Cove	•	140	.171	•	.13	3.47	.50	4.10	5.85
0300	Beams, 5 kip per L.F., 10' span	C-17A	6.28	12.900	C.Y.	187	295	24	506	690
0350	25' span		7.40	10.950		149	250	20	419	575
0500	Chimney foundations, industrial, minimum		26.70	3.030		96	70	5.60	171.60	220
0510	Maximum		19.70	4.110		110	95	7.55	212.55	275
0700	Columns, square, 12" x 12", minimum reinforcing 49		4.60	17.610		205	405	32	642	885
0800	16" x 16", minimum reinforcing		6.25	12.960		178	300	24	502	680
0900	24" x 24", minimum reinforcing		9.08	8.920		158	205	16.40	379.40	510
1000	36" x 36", minimum reinforcing	C-17B	13.39	6.120		147	140	21	308	400
1200	Columns, round, tied, 16" diameter, minimum reinforcing 49		13.02	6.300		263	145	22	430	535
1300	20" diameter, minimum reinforcing		17.35	4.730		243	110	16.50	369.50	455
1400	24" diameter, minimum reinforcing		22.18	3.700		221	85	12.90	318.90	390
1500	36" diameter, minimum reinforcing		32.40	2.530		209	58	8.85	275.85	330
3100	Elevated slabs including finish, not									
3110	including forms or reinforcing									
3150	Regular concrete, 4" slab	C-8	2,685	.021	S.F.	.69	.41	.19	1.29	1.59
3200	6" slab		2,585	.022		1.04	.43	.20	1.67	2
3250	2-½" thick floor fill		2,685	.021		.43	.41	.19	1.03	1.30
3300	Lightweight, 110# per C.F., 2-½" thick floor fill		2,585	.022		.57	.43	.20	1.20	1.49
3400	Cellular concrete, 1-⅝" fill, under 5000 S.F.		2,000	.028		.30	.55	.26	1.11	1.44
3450	Over 10,000 S.F.		2,200	.025		.27	.50	.23	1	1.31
3800	Footings, spread under 1 C.Y.	C-17B	31.82	2.580	C.Y.	84	59	9	152	195
3850	Over 5 C.Y.	C-17C	70.45	1.180		70	27	6.20	103.20	125
3900	Footings, strip, 18" x 9", plain	C-17B	34.22	2.400		66	55	8.35	129.35	165
3950	36" x 12", reinforced		49.07	1.670		70	39	5.85	114.85	145
4000	Foundation mat, under 10 C.Y.		32.32	2.540		107	59	8.85	174.85	215
4050	Over 20 C.Y.		47.37	1.730		103	40	6.05	149.05	180
4200	Grade walls, 8" thick, 8' high	C-15	10.16	7.090		115	150	5	270	360
4250	14' high	C-20	7.30	8.770		172	165	79	416	530
4260	12" thick, 8' high	C-17A	13.50	6		135	140	11.05	286.05	375
4270	14' high	C-20	11.60	5.520		126	105	50	281	350
4300	15" thick, 8' high	C-17B	20.01	4.100		89	94	14.30	197.30	260
4350	12' high	C-20	14.80	4.320		107	82	39	228	285
4500	18' high	•	12	5.330		127	100	48	275	345
4650	Slab on grade, not including finish, 4" thick	C-17C	75.28	1.100		60	25	5.80	90.80	110
4700	6" thick	•	113.47	.731		58	16.85	3.84	78.69	94
4750	Slab on grade, incl. troweled finish, not incl. forms									
4760	or reinforcing, over 10,000 S.F., 4" thick slab	C-8	3,520	.016	S.F.	.65	.31	.15	1.11	1.35
4820	6" thick slab		3,610	.016		.98	.31	.14	1.43	1.70
4840	8" thick slab		3,275	.017		1.30	.34	.16	1.80	2.11
4900	12" thick slab		2,875	.019		1.95	.38	.18	2.51	2.92
4950	15" thick slab		2,560	.022		2.44	.43	.20	3.07	3.55
5200	Lift slab in place above the foundation, incl. forms,									
5210	reinforcing, concrete and columns, minimum	C-17E	745	.107	S.F.	2.34	2.48	.07	4.89	6.45
5900	Pile caps, incl. forms and reinf., sq. or rect., under 5 C.Y.	C-17C	47.28	1.760	C.Y.	76	41	9.20	126.20	155
5950	Over 10 C.Y.		76.47	1.090		70	25	5.70	100.70	120
6000	Triangular or hexagonal, under 5 C.Y.		47.95	1.730		73	40	9.10	122.10	150
6050	Over 10 C.Y.		77.85	1.070		70	25	5.60	100.60	120
6201	Retaining walls, gravity, 4' high	C-17B	19.10	4.290		64	99	15	178	240
6250	10' high		27.10	3.030		66	70	10.55	146.55	190
6300	Cantilever, level backfill loading, 8' high		16.30	5.030		121	115	17.60	253.60	330

171 | S.F., C.F. and % of Total Costs

		171 000 S.F. & C.F. Costs	UNIT	UNIT COSTS ¼	UNIT COSTS MEDIAN	UNIT COSTS ¾	% OF TOTAL ¼	% OF TOTAL MEDIAN	% OF TOTAL ¾
310	2720	Plumbing	S.F.	3.32	4.16	5.60	8%	8.90%	9.6
	2770	Heating, ventilating, air conditioning		3.51	4.03	5.60	4.60%	7.60%	9.9
	2900	Electrical		3.40	4.95	6.10	6.40%	8.70%	9.5
	3100	Total: Mechanical & Electrical		8	13.45	18.35	18.40%	22.50%	29.4
	9000	Per bed, total cost	Bed	10.000	16.000	25.500			
320	0010	*DORMITORIES Mid Rise (4 to 8 story)*	S.F.	70.35	82.55	102			
	0020	Total project costs	C.F.	6.25	8.15	9.70			
	2720	Plumbing	S.F.	5.45	6.35	8	6.40%	10%	10.3
	2900	Electrical		5.65	7.90	9.60	8%	8.90%	10.
	3100	Total: Mechanical & Electrical		14.70	18.10	25.85	18.10%	22.20%	30.6
	9000	Per bed, total cost	Bed	13.600	16.500	21.800			
340	0010	**FACTORIES**	S.F.	24.65	34.45	59.05			
	0020	Total project costs	C.F.	1.81	2.38	3.40			
	2720	Plumbing	S.F.	2.60	3.05	4.59	4.80%	6%	10.4
	2770	Heating, ventilating, air conditioning		2.39	3.86	4.29	5%	6.90%	8.6
	2900	Electrical		3.75	7.65	8.55	8.90%	11.30%	14.4
	3100	Total: Mechanical & Electrical		9.25	15.15	20.95	22.10%	28%	34
360	0010	**FIRE STATIONS**		51.50	69.15	83.80			
	0020	Total project costs	C.F.	3.26	4.43	5.55			
	2720	Plumbing	S.F.	3.31	5.15	7	5.90%	7.30%	9.5
	2770	Heating, ventilating, air conditioning		2.83	4.56	7.25	4.80%	7.30%	9.2
	2900	Electrical		3.84	6.45	9.25	7.10%	9.60%	11.9
	3100	Total: Mechanical & Electrical		9.80	15.20	20.90	17.50%	22.50%	27.5
370	0010	**FRATERNITY HOUSES And Sorority Houses**		50.90	60.75	67.80			
	0020	Total project costs	C.F.	4.87	5.90	6.55			
	2720	Plumbing	S.F.	3.84	4.49	5.95	5.90%	8%	10.8
	2900	Electrical		3.35	4.42	8.05	6.50%	8.80%	10.4
	3100	Total: Mechanical & Electrical		9.50	13.50	16.25	14.60%	20.70%	24.2
380	0010	**FUNERAL HOMES**	S.F.	48.45	61.15	89.25			
	0020	Total project costs	C.F.	3.42	4.92	6.10			
	2720	Plumbing	S.F.	1.92	2.66	2.91	4.10%	4.40%	4.7
	2770	Heating, ventilating, air conditioning		4.27	4.31	5.20	7%	9.20%	10.4
	2900	Electrical		3.20	4.35	6.20	5.90%	7.70%	11%
	3100	Total: Mechanical & Electrical		8.75	11.60	13.40	17.80%	20.80%	27.1
390	0010	**GARAGES, COMMERCIAL (service)**		29.30	46.15	61			
	0020	Total project costs	C.F.	1.86	2.73	3.85			
	2720	Plumbing	S.F.	1.87	2.95	5.95	4.90%	7.30%	11%
	2730	Heating & ventilating		2.76	3.79	4.58	5.20%	7.20%	9.5
	2900	Electrical		2.60	4.28	6	7.10%	9%	11.1
	3100	Total: Mechanical & Electrical		6.05	10.75	15.45	15.50%	21.90%	27.6
400	0010	**GARAGES, MUNICIPAL (repair)**		31.70	49.55	71.80			
	0020	Total project costs	C.F.	2.23	3.23	4.31			
	2720	Plumbing	S.F.	1.94	3.67	6	4.10%	6.90%	8.6
	2730	Heating & ventilating		2.31	3.91	6.60	4.90%	7.60%	11.9
	2900	Electrical		2.82	4.34	5.85	6.60%	8.10%	10.1
	3100	Total: Mechanical & Electrical		6.75	14.50	18.40	16%	24.10%	31.5
410	0010	**GARAGES, PARKING**		16.75	21.10	35.45			
	0020	Total project costs	C.F.	1.45	1.93	3.15			
	2720	Plumbing	S.F.	.30	.59	.85	2.10%	2.80%	3.8
	2900	Electrical		.71	1.04	1.67	4.20%	5.20%	6.5
	3100	Total: Mechanical & Electrical		1.23	1.66	2.46	7.10%	8.50%	9.5
	9000	Per car, total cost	Car	5.375	7.325	10.300			
	9500	Total: Mechanical & Electrical	"	385	580	710			
430	0010	**GYMNASIUMS**	S.F.	44.10	59.35	76			
	0020	Total project costs	C.F.	2.20	3.05	3.90			

For expanded coverage of these items see *Means Square Foot Cost Da*

166 100 | Lighting

	Line	Description	Crew	Daily Output	Man-Hours	Unit	Bare Costs Mat.	Bare Costs Labor	Bare Costs Equip.	Bare Costs Total	Total Incl. O&P
160	0040	Incandescent 24"	1 Elec	2.50	3.200	Ea.	365	80		445	520
	0050	Incandescent 36"		2	4		440	100		540	635
	0060	Incandescent 42"		2	4		465	100		565	660
	0070	H.I.D. 24"		2.50	3.200		345	80		425	500
	0080	H.I.D. 36"		2	4		385	100		485	570
	0090	H.I.D. 42"		2	4		525	100		625	725
	0100	Concrete 18" dia.		1.20	6.670		990	170		1,160	1,325
	0110	Concrete 24" dia.		.75	10.670		1,250	270		1,520	1,775
	0120	Dry niche									
	0130	300 W 120 Volt	1 Elec	4	2	Ea.	540	50		590	670
	0140	1000 W 120 Volt		2	4		720	100		820	940
	0150	300 W 12 Volt		4	2		540	50		590	670
	0160	Low voltage									
	0170	Recessed uplight	1 Elec	2.20	3.640	Ea.	295	91		386	460
	0180	Walkway		4	2		265	50		315	365
	0190	Malibu - 5 light set		3	2.670		190	67		257	310
	0200	Mushroom 24" pier		4	2		195	50		245	290
	0210	Recessed, adjustable									
	0220	Incandescent 150 W	1 Elec	2.50	3.200	Ea.	435	80		515	595
	0230	Incandescent 300 W		2.50	3.200		500	80		580	670
	0240	Mercury vapor 175 W		2	4		530	100		630	730
	0250	Recessed uplight									
	0260	Incandescent 50 W	1 Elec	2.50	3.200	Ea.	350	80		430	505
	0270	Incandescent 150 W		2.50	3.200		365	80		445	520
	0280	Incandescent 300 W		2.50	3.200		410	80		490	570
	0290	Mercury vapor 50 W		2	4		445	100		545	640
	0300	Mercury vapor 175 W		2	4		470	100		570	665
	0310	Quartz 500 W		2.50	3.200		405	80		485	565
	0400	Recessed wall light									
	0410	Incandescent 100 W	1 Elec	4	2	Ea.	150	50		200	240
	0420	Fluorescent		4	2		135	50		185	225
	0430	H.I.D. 100 W		3	2.670		270	67		337	395
	0500	Step lights									
	0510	Incandescent	1 Elec	5	1.600	Ea.	135	40		175	210
	0520	Fluorescent		5	1.600		170	40		210	245
	0600	Tree lights, surface adjustable									
	0610	Incandescent 50 W	1 Elec	3	2.670	Ea.	330	67		397	460
	0620	Incandescent 100 W		3	2.670		345	67		412	480
	0630	Incandescent 150 W		2	4		370	100		470	555
	0700	Underwater lights									
	0710	150 W 120 Volt	1 Elec	6	1.330	Ea.	315	34		349	395
	0720	300 W 120 Volt		6	1.330		360	34		394	445
	0730	1000 W 120 Volt		4	2		995	50		1,045	1,175
	0740	50 W 12 Volt		6	1.330		330	34		364	415
	0750	300 W 12 Volt		6	1.330		390	34		424	480
	0800	Walkway, adjustable									
	0810	Fluorescent, 2'	1 Elec	3	2.670	Ea.	235	67		302	360
	0820	Fluorescent, 4'		3	2.670		250	67		317	375
	0830	Fluorescent 8'		2	4		490	100		590	690
	0840	Incandescent 50 W		40	.200		220	5.05		225.05	250
	0850	Incandescent 150 W		4	2		240	50		290	340
	0860	Mercury vapor 150 W		3	2.670		305	67		372	435
	0870	Mercury vapor 175 W		3	2.670		335	67		402	470
	0900	Wet niche									
	0910	300 W 120 Volt	1 Elec	2.50	3.200	Ea.	570	80		650	745
	0920	1000 W 120 Volt		1.50	5.330		750	135		885	1,025
	0930	300 W 12 Volt		2.50	3.200		565	80		645	740

For expanded coverage of these items see Means Electrical Cost Data

ICF KAISER ENGINEERS

JOB NO 04 [illegible]
SHEET 1 OF 1

GROUNDWATER TREATMENT SYSTEM
PRETREATMENT (PRECIPITATION)

DESIGNED BY NNA DATE 3
CHECKED BY [illegible] DATE 3

Electrochemical Precipitation

- consists of reactor (electrochemical unit), tanks, clarifier, multi-media granular media filtration unit, filter-press all logically controlled with programmable logic controller.
- Capital Costs \$700,000 - \$850,000
- Annual Costs \$0.20 - 0.25 / 1000 gal
  includes power maintenance, and chemicals
  \$0.25 / 1000 gal × 262,800,000 gal/yr = \$65,700/yr
- Sludge removal Costs
  approx 15 ft³/day of sludge will be produced @ a cost of \$180 / 55 gal drum for removal.

$$\Rightarrow 15\ \frac{ft^3}{day} \cdot 7.48\ \frac{gal}{ft^3} \cdot \frac{\$180.00}{55 gal\ drum} \cdot 365\ \frac{day}{yr}$$

$$= \$134,000 / yr$$

- Operator Costs
  Requires 1 operator - 2 hrs/day

- Dimensions 50' × 40' × 25' high

Source: ANDCO Environmental Processes, Amherst, NY
Dan Waytena (716) 691-2100

CALCULATIONS KE Form No E-6 Rev 12-89

ICF KAISER ENGINEERS

Job No

Sheet / of /

GROUNDWATER TREATMENT SYSTEM

PRETREATMENT (GMF)

DESIGNED BY NNA DATE 3

CHECKED BY JM DATE 6

GRANULAR MEDIA FILTRATION UNIT

- consists of influent and effluent tanks, filter skid with pumps (3 vessel multi-media filter)
- Capital Costs $95,000
- Annual Costs

assume approx $0.20 /1000 gal

$\$0.20/1000\,gal \times 262{,}800{,}000\,gal/yr = \$52{,}500/yr$

- Operator costs

Requires 1 operator - 2 hrs/day

Source: ANDCO Environmental Processes, Amherst, NY
Dan Waytena, (716) 691-2 0

CALCULATIONS KE Form No E-6 Rev 12 89

ICF KAISER ENGINEERS

Job No C420-...

Sheet 1 of 1

MAAP Feasibility Study
UV-OXIDATION Costs.

DESIGNED BY JKM DATE

CHECKED BY MCM DATE 3.

Capital Costs: $1,400

- 500 gpm system
- Equipment includes
  - 3 - 5000 gal contactors for preoxidation
  - 4 - 3900 gal reactors
  - 800 lbs/day of ozone generation

Annual Costs: $5

$2/1000 gal treated
- price includes H_2O_2, ozone and electrical costs.

Assuming a rate of 500 gpm → 2.63×10^8 gallons processed per year

$$2.63 \times 10^8 \text{ gallons to be treated} \times \frac{\$2}{1000 \text{ gallons to be treated}} = \$526,000$$

Part time assistance operator:

Estimated checkup time is 1 hr. per day

365 hrs per year

Cost information supplied by Ultrox International.

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ICF KAISER ENGINEERS

JOB No 04302003[illegible]

SHEET 1 OF 1

Granular Activated Carbon Costs

DESIGNED BY JM DATE 3

CHECKED BY MCM DATE 3

Carbon costs obtained from Calgon Carbon. Disposal costs obtained by Solvent Recovery Corp

Capital Costs:

one model-10 adsorber (which contains 2-20,000 lb adsorbers) — $165

TOTAL capacity - 40,000 lbs carbon.

Annual Costs:

CARBON COSTS — $956

Assume 500gpm system:

Usage rate estimated by Calgon carbon: 1656 lbs/day.

1,656 lbs/day x 365 day = 604,444 lbs/yr.

Cost for carbon replacement and delivery: $16,000/20,000 lbs.

Deliveries of Carbon will be needed approximately 15 times/yr.

$16,000/20,000 lbs x 604,444 lbs/yr = $483,555

↓

$480,000 for carbon delivery and replacement. — $480

DISPOSAL COSTS: — $476

Based on MAAPs current drum disposal costs,

Drums are ~ 7.5 lb/gal

BTU content ~ 6200 Btu/lb - 8500 Btu/lb.

current cost/drum is $300 - $325 per drum.

7.5 lbs/gal x 55 gal/drum ≐ 413 lbs/drum

$\frac{1,656 \text{ lbs/day}}{413 \text{ lbs/drum}}$ · $325/drum x 365 days = $475,649

↓

$476,000

CALCULATIONS KE Form No E-6 Rev 12-89

ICF KAISER ENGINEERS

JOB NO 0A20-00200 SHEET 1 OF 1

UV-OXIDATION & GAC Combined in treatment (Alternative T-7 & T-8)

DESIGNED BY JM DATE

CHECKED BY MCM DATE

Prices obtained from Ultrox International, Calgon Carbon & Solvent Recovery.

Capital Costs:

UV-oxidation : $980,000
(estimated to be 70% of cost using UV-oxidation as sole treatment for organics).

Carbon unit : $165,000

$1,145,000

Annual Costs:

UV-oxidation:

$1.40/1000gal × 500gal/minute × 1440min/day × 365day/yr
(estimated to be 70% of cost using UV-oxidation as sole treatment for organics).
= $367,920/yr

Carbon Adsorption:

Usage rate is approximately 0.2lb/1000gallons

0.2lbs/1000gallons × 500gal/min × 1440min/day × 365day/yr

= 52,560 lbs/yr

Cost for carbon and delivery –

$1/lb × 52,560 lbs/yr = $52,560/yr

Disposal of carbon.

Present Cost of disposal of carbon drums at MAAP → $325/drum.

Assume same cost. Assume 7.5 lb/gal

7.5 lbs/gal × 55gal/drum ≅ 413 lbs/drum

• (52,560 lbs/yr) / (413 lbs/drum) × $325/drum = $41,361/yr →

TOTAL ANNUAL COSTS: $238,461

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ICF KAISER ENGINEERS

Job No 0432620...

Sheet 1 of 1

ION EXCHANGE COSTS

DESIGNED BY JM DATE 3-

CHECKED BY MCM DATE 3.

Costs Provided By Mobile Water Technology.

No capital costs. Equipment is replaceable per month

ANNUAL COSTS: $964

equipment (including resin and upkeep of equipment) → $136

$11,400/month × 12 = $136,800

waste treatment, recycle, transport → $82

$13,60- every ' ays

$13,6.../6days × ...5days = $827,333

TOTAL: $964,133

↓

$964,000

ICF KAISER ENGINEERS

Job No ____

Sheet 1 of 3

O LINE PONDS FS
EXTRACTION / TREATMENT ALTERNATIVES
REINJECTION SYSTEM

DESIGNED BY RP DATE
CHECKED BY GM DATE

REINJECTION SYSTEM COMPONENTS

1. INJECTION WELLS
2. INJECTION PUMPS
3. DISTRIBUTION PIPING
4. SYSTEM CONTROLS

1. INJECTION WELLS

CAPITAL COSTS

3 - 6" Ø WELLS PVC CASING, PVC SCREEN SLOT SIZE 0.0(
(IDENTICAL IN CONSTRUCTION MATERIALS TO EXTRACTION WELLS)
INJECTION WELLS SHOULD SCREEN ENTIRE AQUIFER
⇒ ∴ 300' TOTAL DEPTH, SCREENED FROM 40' TO 300'.

300' @ $110 / ft / well = $33,000 / well

3 wells @ $33,000 / well = $99,000

O&M COSTS

MAINTENANCE OF INJECTION WELLS MIGHT INCLUDE PUMPING WATER FROM THE WELL TO REMOVE INCRUSTANTS, CHEMICAL TREATMENT, ETC

ASSUME 10 DAYS / YR FOR MAINTENANCE, $500 / DAY INCLUDING LABOR & MATERIALS = $5,000

CALCULATIONS KE Form No E-6 Rev 12 89

ICF KAISER ENGINEERS

JOB No ______

SHEET 2 OF 3

O LINE PONDS FS
EXTRACTION / TREATMENT ALTERNATIVES
REINJECTION SYSTEM

DESIGNED BY RB DATE 3

CHECKED BY DM DATE 3

2. INJECTION PUMPS

CAPITALS COSTS

FIRST DETERMINE REQUIRED PUMP HORSEPOWER

$$\text{PUMP HP} = \frac{Q \gamma H}{550} / \text{EFFICIENCY}$$

WHERE Q = DISCHARGE RATE (FT^3/SEC)

γ = 62.4 LBS/FT^3

H = TOTAL DYNAMIC HEAD (FEET)

H INCLUDES FRICTION LOSSES IN PIPE, AND FACTORS IN PERMEABIL OF MATERIAL WATER IS BEING INJECTED INTO.

ASSUME 500 GPM TO BE DELIVERED TO 3 INJECTION WELLS

$\therefore \doteq$ 170 GPM PER INJECTION WELL

1 GPM = 2.22×10^{-3} FT^3/SEC

170 GPM = 0.3774 FT^3/SEC

$$HP = \frac{(0.3774)(62.4)(150)}{550} / 0.5$$ (ASSUME 50% PUMP EFFICIENC

HP = 12.84

SAY 13 HP IS BRAKE HORSEPOWER REQUIRED

GELBER INDUSTRIES PRODUCT CATALOG 1989

MODEL # JB 200-SS-2000 13 HP ODP $2915

SAY $3200 FOR TOTALLY ENCLOSED FAN COOLED PUMP

ADD 10% FOR INFLATION $3,520/pump

3 pumps @ $3,520/pump = $10,560

O+M COSTS

OPERATION COST PER PUMP CALCULATE (KW-HRs REQUIRED)($/

= (13 HP)(0.7457 KW/HP)(24 HR/DAY)(365 DAY/YR)($0.10/K

= $8,492 SAY $8,500/PUMP

3 PUMPS @ $8,500/PUMP = $25,500

CALCULATIONS KE Form No E-6 Rev 12 89

ICF KAISER ENGINEERS

Job No

0 LINE PONDS FS
EXTRACTION / TREATMENT ALTERNATIVES
REINJECTION SYSTEM

DESIGNED BY RB DATE
CHECKED BY m DATE

MAINTENANCE COST PER PUMP SAY $100/YR/PUMP
3 PUMPS x $100/YR/PUMP = $300/YR

TOTAL O+M COSTS:

(O)	3 x $8,500	$25,500
(M)	3 x $100	$ 300
		$25,800

3. DISTRIBUTION PIPING

COSTS FOR THIS ELEMENT ARE PRESENTED IN ANOTHER PORTION OF THIS APPENDIX.

4. SYSTEM CONTROLS

- MECHANICAL

ASSUME CHECK VALVES BALL VALVES MISCELLANEOUS FITTINGS ARE REQUIRED
SAY $5,000

- ELECTRICAL

IT IS DIFFICULT TO PROVIDE A GOOD ESTIMATION FOR THIS UNTIL THE SYSTEM IS CONCEPTUALLY DESIGNED.
A COST OF $20,000 IS USED AS A BALLPARK NUMBER TO ACCOUNT FOR THIS ITEM. THIS WOULD INCLUDE DEVELOPMENT AND INSTALLATION OF THE ELECTRICAL CONTROL SYSTEM INCLUDING WIRING, SWITCHES, CONTROL PANELS, TRANSFORMERS AND OTHER ELECTRICAL COMPONENTS

	$ 5,000
TOTAL	$20,000
	$25,000

ICF KAISER ENGINEERS

JOB No ____________

SHEET 1 OF 1

RE-INJECTION SYSTEM COSTS
PIPING

DESIGNED BY NNA DATE

CHECKED BY JM DATE

Discharge Piping

same piping set-up as for extraction system.

Source: Means site, 1991
Insulation - Accessible Products Co, Tempe, Arizona

Unit costs

- schedule 40 galvanized steel pipe (6" diameter) $57.00/LF
  - materials and labor
- Polyurethane insulation with jacket $13.26/LF
  - 1½" thick
  - jacket constructed of polyester fabric PVC impregnated
  - supplied with silicone sealant

Total Unit Cost $70.26/LF

Re-Injection Piping

$316,0

DISCHARGE WELL	DISTANCE FROM TREATMENT PLANT TO RE-INJECTION WELL (FT)	Piping Costs
DW-1	1300	$ 91,338
DW-2	1500	$ 105,390
DW-3	1650	$ 115,929
	4,450 Ft	$ 312,657
	Freight	$ 3,000
		$ 315,657
		$ 316,000

ICF KAISER ENGINEERS

Job No ______

Sheet 1 of 1

SURFACE WATER DISCHARGE COSTS
PIPING

DESIGNED BY NNF DATE
CHECKED BY MM DATE

Discharge Piping

same piping set-up as for extraction system.

Source: Means Site, 1991
Insulation - Accessible Products Co, Tempe, Arizona

Unit Costs

- Schedule 40 galvanized steel pipe (6" diameter) — $57.00/LF
  - materials and labor
- Polyurethane insulation w/jacket — $13.26/LF
  - 1½" thick
  - jacket constructed of polyester fabric PVC impregnated
  - supplied with silicone sealant

Total Unit Cost $70.26/LF

- Assume Distance from treatment plant to surface water discharge point is 8500 linear feet. $600,

8500 LF x $70.26/LF = $597,210

Freight 4,000

$601,210

↓

$600,000

151 | Pipe and Fittings

		151 700 Steel Pipe	CREW	DAILY OUTPUT	MAN-HOURS	UNIT	BARE COSTS MAT	LABOR	EQUIP	TOTAL	TC INC
701	0010	PIPE, STEEL									
	0020	All pipe sizes are to Spec. A-53									
	0050	Schedule 40, threaded, with couplings, and clevis type									
	0060	hangers sized for covering, 10' O.C.									
	0540	Black, ¼" diameter (129)	1 Plum	66	.121	L.F.	.75	3.08		3.83	
	0550	⅜" diameter		65	.123		.84	3.13		3.97	
	0560	½" diameter		63	.127		.90	3.23		4.13	
	0570	¾" diameter		61	.131		1.06	3.34		4.40	
	0580	1" diameter		53	.151		1.49	3.84		5.33	
	0590	1-¼" diameter	Q-1	89	.180		1.85	4.12		5.97	
	0600	1-½" diameter		80	.200		2.17	4.58		6.75	
	0610	2" diameter		64	.250		2.91	5.75		8.66	
	0620	2-½" diameter		50	.320		4.78	7.35		12.13	
	0630	3" diameter		43	.372		6.19	8.50		14.69	
	0640	3-½" diameter		40	.400		8.61	9.15		17.76	
	0650	4" diameter		36	.444		9.76	10.20		19.96	
	0660	5" diameter		26	.615		16.93	14.10		31.03	
	0670	6" diameter	Q-2	31	.774		21.94	18.40		40.34	
	1220	To delete coupling & hanger, subtract									
	1230	¼" diam. to ¾" diam.					31%	56%			
	1240	1" diam. to 1-½" diam.					23%	51%			
	1250	2" diam. to 4" diam.					23%	41%			
	1260	5" diam. to 12" diam.					21%	45%			
	1290	Galvanized, ¼" diameter	1 Plum	66	.121	L.F.	1	3.08		4.08	
	1300	⅜" diameter		65	.123		1.18	3.13		4.31	
	1310	½" diameter		63	.127		1.14	3.23		4.37	
	1320	¾" diameter		61	.131		1.30	3.34		4.64	
	1330	1" diameter		53	.151		1.81	3.84		5.65	
	1340	1-¼" diameter	Q-1	89	.180		2.26	4.12		6.38	
	1350	1-½" diameter		80	.200		2.74	4.58		7.32	
	1360	2" diameter		64	.250		3.53	5.75		9.28	
	1370	2-½" diameter		50	.320		5.67	7.35		13.02	
	1380	3" diameter		43	.372		7.39	8.50		15.89	
	1390	3-½" diameter		40	.400		9.71	9.15		18.86	
	1400	4" diameter		36	.444		11.29	10.20		21.49	
	1410	5" diameter		26	.615		20.93	14.10		35.03	
	1420	6" diameter	Q-2	31	.774		26.54	18.40		44.94	
	1430	8" diameter		27	.889		38.48	21		59.48	
	1440	10" diameter		23	1.040		55.24	25		80.24	
	1450	12" diameter		18	1.330		67.34	32		99.34	
	1750	To delete coupling & hanger, subtract									
	1760	¼" diam. to ¾" diam.					31%	56%			
	1770	1" diam. to 1-½" diam.					23%	51%			
	1780	2" diam. to 4" diam.					23%	41%			
	1790	5" diam. to 12" diam.					21%	45%			

		151 800 Grooved-Joint Steel Pipe	CREW	DAILY OUTPUT	MAN-HOURS	UNIT	MAT	LABOR	EQUIP	TOTAL	TC INC
801	0010	PIPE, GROOVED-JOINT STEEL FITTINGS & VALVES									
	0020	Pipe includes coupling & clevis type hanger 10' O.C.									
	1000	Schedule 40, black									
	1040	¾" diameter	1 Plum	71	.113	L.F.	2.01	2.87		4.88	
	1050	1" diameter		63	.127		2.19	3.23		5.42	
	1060	1-¼" diameter		58	.138		2.71	3.51		6.22	
	1070	1-½" diameter		51	.157		3.01	3.99		7	
	1080	2" diameter		40	.200		3.60	5.10		8.70	
	1090	2-½" diameter	Q-1	57	.281		5.03	6.45		11.48	
	1100	3" diameter	•	50	.320		6.09	7.35		13.44	

For expanded coverage of these items see *Means Mechanical Cost Data or Means Plumbing Cost Da:*

ICF KAISER ENGINEERS

Job No 043120030

Sheet 1 of 1

QUARTERLY GROUNDWATER MONITORING
& SURFACE WATER MONITORING
+ REPORTING

DESIGNED BY Mm DATE 3

CHECKED BY MCM DATE 3

FOR ONE GW MONITORING: 6 samples collected

Analysis for TAL/TCL, Explosives & Cyanide → $2000/sample

$2000 × 6 = $12,000 — $12,0

Labor, equipment, travel & per diem: — $ 4,

1 trip, 2 days

2 people

airfare	$600 each × 2 =	$1200
per diem	$75/day × 2 people × 2 =	$300
car		$160
		$1,660
Equipment and H & S	+	600
		$2260
Reporting:	+	$2,500
		$4,760

TOTAL PER SAMPLING EVENT: — $16,

TOTAL FOR QUARTERLY GROUNDWATER MONITORING & REPORTING — $67,

$16,760 × 4 = $67,040

↓

$67,000

QUARTERLY SURFACE WATER MONITORING & REPORTING: — $67,

Assume 6 samples collected per sampling event.

All costs assumed to be the same as above.

TOTAL COST => $67,000

CALCULATIONS KE Form No E-6 Rev 12-89

ICF KAISER ENGINEERS

Job No 0430200300

Sheet 1 of 1

Weekly Effluent & Monthly Residuals Monitoring

DESIGNED BY JM DATE 3

CHECKED BY MCM DATE 3

ONLY analytical costs are included.

WEEKLY EFFLUENT

$ 104

Weekly Effluent to be analyzed for TAL/TCL, Explosives + cyanide.

Price per sample → $2000 /

Price for one year of sampling → $2000 x 52 = $104,000

MONTHLY RESIDUALS

$ 16,8

Worst case → 2 samples collected per month if using GAC and chem ppt.

Residuals to be tested for (Prices obtained from Keystone labs, 1990)

TCLP metals →	$190
TCLP VOCs →	$335
Corrosivity →	$30
Ignitability →	$10
Reactivity →	$65
	$630 + 5% = $662, say, $700 per sample

2 samples/month × 12 month/yr × $700/sample = $16,800

TOTAL: $120,800 → $121,000

$121,

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